Music and the Transhuman Ear: Ultrasonics, Material Bodies, and the Limits of Sensation

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We favor morphological freedom—the right to modify and enhance one’s body, cognition and emotions.

—Transhumanist declaration, 2012

I am apt to think, if we knew what it was to be an angel for one hour, we should return to this world, though it were to sit on the brightest throne in it, with vastly more loathing and reluctance than we would now descend into a loathsome dungeon or sepulchre.

—George Berkeley, 1732

I

The Materialist Turn

When Voyager probes 1 and 2 left Earth’s orbit in 1977, the committee tasked with assembling cultural artifacts followed scientist Lewis Thomas’s advice to include recordings of J. S. Bach among the many musical samples. This, it seems, was the best way to open a conversation with an unknown non-human interlocutor, wherein exchanges may be spaced hundreds of years apart. Many styles and genres were committed to the golden discs, but Thomas worried that by broadcasting Bach, the human race might be guilty of bragging to aliens: “We would be bragging, of course,” he admitted in 1972, “but it is surely excusable to put the best possible face on at the beginning of such an acquaintance.”

His statement

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makes telling assumptions. To take one example, the three-voice C-major fugue Glenn Gould recorded (WTC, Book II) matches humans’ ability at auditory streaming, which, as David Huron has shown, tends to max out at around three streams, after which “confusions [over contrapuntal lines] become commonplace.”

It would seem that part of the effect of Bach’s polyphony depends on precisely that limitation, but there is no reason to suppose that a hypothetical alien would have the same limitation (if it were sensitive to this frequency range); the alien might just as easily find Bach’s fugue elementary, even trivial.

Extrapolating from this distancing exercise, this article is about transhumanism and hearing. It takes a lateral approach to writings in the history of materialism to plot a course for the human ear between two reciprocal paradigms: a receptacle of vibrational force and an augmentable prosthesis creating new sensory feedback. These two paradigms structure the article’s two parts: Part I sets out the materialist context, including—a study of empirical sense augmentations (and their illusions) in the nineteenth century; Part II extrapolates from this a critique of hearing-enhancing technologies that exist today under the tenets of transhumanism.

The past decade has witnessed entwined debates over listening and media, in which contributors have sought to place both the sonic phenomenon and the experience of performed music at the heart of the matter. I would like to begin with two—I hope uncontroversial—claims: performance acts necessitate a witness, however remediated they become; and music, as something that is perceived, is a sensible phenomenon. Ears and eyes structure our relation to music, while at the same time being constitutive of our sense of self within an environment; as apparatus for mediating sound and light they attest to the body as “the pivot of the world” in Maurice Merleau-Ponty’s memorable phrase. Approaches to sound as vibrational event imply a need to relativize hermeneutic or metaphysical knowledge with a theory of matter. Despite a long tradition of philosophical materialism in the West, such disciplinary reorientation is potentially unsettling. After all, music can animate matter, and as Carolyn Abbate reminds us, it “can ban logos or move our bodies without our conscious will.” Without reifying sonic communication, such a condition defines sound’s communicative agency itself as animate matter—a delicate dance of vibration and physiology.

Historically, this view first gained credence in the mid-nineteenth century when Hermann von Helmholtz posited the ear as a mechanism for sympathetic vibration: “a peculiar apparatus, partly elastic, partly firm, which may be put in sympathetic vibration under the influence of external vibration.” Stemming from this, and adapting Brian Massumi’s formulation of affect, we may say the vibrations of the haptic environment touch us
manifestly and without prejudice, impacting listeners with a “prepersonal intensity corresponding to the passage from one experiential state of the body to another.” In this reading, the communication network is primarily between bodies: “an encounter between the affected body and a second, affecting body.” It applies as much to the plucking of a monochord as to a subwoofer’s vibrations that palpably shake us. This is not to deny the life of the mind—from what is phenomenologically given to the mind, to the truism that even during absorption in performance we may reflect momentarily on formalist or hermeneutic meanings—only that once music as sounding experience becomes an object of study, the sensory means by which we register that experience are also implicated as structural constituents of the identity of that music.

So far so good. But there are already compositions whose sound exceeds human sense capacity. The totality of their performance is unavailable to us, in other words, which is to say: literally non-sensical.

Two examples concern pitch and duration:

1. There are ultrasonic dog whistles in Per Nørgård’s Fifth Symphony (1994), and seemingly inaudible harmonics in Schoenberg’s Violin Concerto (b9 at mm. 544 and 567, given in ex. 1), which André Mangeot declared “beyond the musical range of any ear” because at 3,951 Hz their pitch and relative consonance become impossible to discern.

2. Consider the inhuman length of John Cage’s “As Slow as Possible” for organ (1987), whose ongoing performance in Halberstadt—lasting 639 years—will exceed an average American life span by a ratio of 8:1. As Alexander Rehding notes, there can be “no performer in the ordinary sense” for this work, and indeed the work concept itself falters “for the simple reason that it is humanly impossible to hear the piece from beginning to end.”

If we accept the view that musical performance is to be understood as lived experience, bodies that could conceivably perceive the totality of these works are not ordinarily human. In the context of Bach’s alien we may ask: For whom are such super-sensory effects intended? Who, in such contexts, is the listener?

To an extent, this line of inquiry recontextualizes a familiar eighteenth-century empiricist debate about reality: George Berkeley’s immaterialist proposition that “the objects of sense exist only when they are perceived” (which finds parlance today as the old adage about a tree falling in a wood). For present purposes, it is a related, potential blind spot of semiotic approaches to music that reveals common assumptions about the “normal” body at the dawn of the twentieth century. We recall that Charles
S. Peirce, in 1909, saw a triadic relation between sign, object, and interpretant wherein the latter becomes an active witness to the sign, and actively makes the bond between sign and object. Signs nevertheless retain their absolute character in this bonding, for what Peirce grandly calls the “final interpretant” constitutes nothing less than “the effect the Sign would produce in any mind upon which the circumstances should permit it to work out its full effect.” With a similar rationale, Wolfgang Ernst calls acoustic sound “the deceptive [tip] of an iceberg” vis-à-vis the vast, inaudible electromagnetic spectrum. By definition, music insensible to us does not work out its full effect, reminding us that Peircean semiotics presupposes a known receptor apparatus in the (human) interpretant. Semiotic approaches to music have arguably been enthralled by this Berkeleyian complement: signs or signals only become such—that is, tangibly received stimulation—upon contact with a witness’s means of perception.

**Hearing Ultrasonics ca. 1876**

Historically, the realization that one’s reality depends on what a limited sensory perception can register came to a head most clearly in the last quarter of the nineteenth century, shortly before Pierce’s “final interpretant,” when German scientists debated the upper threshold of human hearing within the triangulated framework of physiology, emergent phenomenology, and empirical psychology. It caused a minor scandal that is worth recalling here for the startling readiness with which sensory limits were rewritten.

During the 1870s, the Hanau-based German instrument maker Anton Appunn produced a series of thirty-one high-pitched tuning forks. These were listed as corresponding to the 4.5 octaves of the diatonic scale, from c⁴
to $e^8$. After empirical studies based on these unprecedented objects, the Anglo-German physiologist Wilhelm Preyer issued a striking claim in 1876:

Thus we can lay to rest the doubt, repeated all too often, as to whether or not it is possible to hear from 24,000 up to 40,000 double vibrations per second. It appears we can not only perceive tones in this omitted eighth octave, but also differentiate them.21

Empirical work with Preyer’s listening subjects appeared to prove the upper threshold for hearing was somewhat higher than previously thought. To look at a chain of prior acousticians researching the same phenomenon, he infers, is to plot a rising auditory threshold for humankind. Joseph Sauveur (6,400 Hz, $g^5$), Ernst Chladni (8,192 Hz, $c^4$), and Jean Baptiste Biot (8,198 Hz, $c^6$) were seemingly adrift by William Hyde Wollaston (25,000 Hz, $g^7$) and César-Mansuète Despretz (36,864 Hz, $d^8$), the latter of whom only refrained from venturing higher, we learn, because he was unable to make a smaller fork resonate. 22

By autumn 1875, Preyer had pipped his immediate rival by a whole tone, achieving what he gave as an audible $e^8$ at 40,960 Hz with a midget fork 13 mm long, 14 mm wide, with prongs 3 mm thick. Human hearing had not been rising in convenient synchrony with each researcher, he concluded, so the new threshold too was quite possibly limited only by the ability to engineer a suitably resonating fork rather than the physiology of the ear, which continued to recognize relative pitch:

> I and several others have heard all 31 tones often, and, if they resound along the row from $c^6$, I recognize quite clearly that they rise up to $e^8$ [40,960 Hz]. Until $c^7$ we hear the scale without difficulty. To be sure, pitches in the 7th and 8th octaves are close to being very painful; nevertheless we recognize they always rise and we hear the octaves very well until $e^8$. . . . One cannot claim, though, that it is impossible to bring forth even higher tones just because the $e^8$ fork becomes silent when shortened further. For it must be proven whether it still vibrates at all after shortening, and indeed encounters sufficiently strong vibrations, before we conclude the ear falls short.23

The exact pitch of Appuhn’s highest fork was debated, and Preyer appears to have been unaware that for different commentators this “exceedingly diminutive” object resonated at either 49,152 Hz or 50,880 Hz.24 Nevertheless, his eye-widening claim that a bowed fork was audible to humans at 40,960 Hz and that our physiological limit may be higher still received a supreme endorsement when Helmholtz repeated it uncritically in the fourth edition of *Die Lehre von den Tonempfindungen* (1877).25 This augmented auditory range “shows what a great variety of different pitch
numbers can be perceived and distinguished by the ear,” he remarked of the eleven octaves between 20 Hz and 40,000 Hz. “In this respect the ear is far superior to the eye,” he concluded in a countercultural opinion that would hold little sway over the visualist bias of the age.26

Helmholtz had no reason to doubt Preyer’s science, which also examined the lowest perceivable frequencies, and identified silence as “a true, positive sensation . . . different from deafness.”27 The Appunn family had long supplied tuning forks to Helmholtz, and Georg Appunn (père) had lectured in Leipzig during the 1860s, supporting Helmholtz’s work and helping to popularize it in print. There was a mutual bond of trust, it seems.28 Other endorsements of Preyer’s work ensued, owing partly to the knowledge that it was based on a new, more accurate method of tuning the highest forks.29 Before 1876, forks above c^7 were tuned by means of the ear alone, typically by locking into the overtones of lower octaves, but Rudolph König had demonstrated as early as 1858 that from the range c^6–c^7 this method was highly inaccurate even with the best trained musicians.30 Between 1874 and 1876, König first effected the tuning of high-pitched rods (professing audibility up to 20,480 Hz) according to their beats; Preyer followed suit with his forks, and appeared to trump his fellow instrument maker by some 20,000 Hz.

König was skeptical from the outset.31 It fell to physicist Franz Emil Melde to prove in 1894—the year of Helmholtz’s death—that Appunn’s forks and corresponding pitch pipes were mistuned by between a minor third (c^6 fork) and a full octave (c^7 fork). “The highest pipe was only ca. 11,000 rather than ca. 50,000 vibrations,” explained one commentator, continuing that the “forks too showed errors of up to ca. 36,000 vibrations.”32 It was Carl Stumpf and Max Meyer who finally put a stop to Preyer’s auditory inflation when, in 1897, they verified Melde’s assertion using a proof based on difference tones.33 When Stumpf returned to the fray in 1899, he refuted Preyer’s protest that a visual proof (optischer Nachweis) of his ultrasonic pipes and forks may be at hand: “Our results have been confirmed by experiments,” Stumpf explains, referring to visual experiments by his assistant Friedrich Schulze.34 In fact it was König who delivered visual evidence of the behavior of inaudible tones later that year. This included sound figures made by the movement of cork dust within a tube vibrating at frequencies of up to 90,000 Hz, that is, photographs of ultrasonic frequencies. Figure 1 shows the ghostly traces of c^9 to f^9 alongside two figures depicting 90,000 Hz. König professes to have measured the frequencies according to beat tones, hence the cryptic dotted lines reveal little to the eye, but serve as an emblem of the empirically inaudible: captured, real “sound” that exists beyond our physiological sense capacity.35
That serious acousticians—Helmholtz included—believed for eighteen years that our auditory range was twice the size previously thought suggests a collective contemporary skepticism toward the limits of human sensory perception. While there need be no direct link here to

Figure 1. Rudolph König’s creation of Kundt acoustic figures at ultrasonic frequencies. In König, “Ueber die höchsten hörbaren und unhörbaren Töne,” Annalen der Physik und Chemie 69 (1899): 649.
a Nietzschean Übermensch, a certain restless anthropocentrism is evident. Crudely put, if nature equipped us even more handsomely than we thought, and we continue to evolve, who or what has the authority to limit humanity? One contemporary example of such an attitude is the German entomologist Karl Ernst de Baer, who was confident humans could hear up to 48,000 Hz sixteen years before Preyer “verified” it. In a lecture from May 1860 he blends fantasy with rationalism to present listeners with a thought experiment concerning sensory limits. It goes as follows: if a human life span of eighty years consists of 29,200 days, and this were to pass by 1,000 times faster giving a compressed life span of twenty-nine days, which could again be sped up by a factor of 1,000, it would result in a total life span of 40–42 minutes, and the corresponding rate of perception would be a million times faster than usual. For such a person, the organic world would probably appear disappointingly static, but other experiences currently unavailable to us would be accessible, de Baer suggests. “All the sounds we hear would certainly be inaudible to such people, if their ears remain morphologically similar to ours; but perhaps they would perceive sounds that we do not hear, indeed perhaps they would even hear light that we see.”

Returning to the first temporal compression (one-thousandth of a full life), he calculates that the highest sounds we perceive, vibrating at 48,000 times between two pulsations, would vibrate only 48 times between pulsations for people of shortened life span, hence they would sound low. At the upper end, even the second compression, resulting in a 42-minute life, would not quite open up our perceptual apparatus to an ether vibrating at “several hundred billion times a second,” he argues,

but we could take the idea of shortening a real life further, until these vibrations of the ether, which we currently experience as light and color, actually become audible. And might there yet be in nature quite different vibrations which are too fast for us to experience as sound, and too slow to appear to us as light? ... It is not at all preposterous to believe so. ... Is there not perhaps a sounding of outer space ... that is audible to ears quite different to ours?

The quasi-scientific postulate of alien auditory realities, and the apparently simple manner of calculating their relation to lived experience, suggest the degree of fascination that limited perception held for those ambitious for human nature.

It is indicative, then, that only a few years after Preyer’s ultrasonic claims were rubbished, Ezra Pound would speculate on “new organs” for the body of the artist, whose brain constitutes largely undischarged chemical potential, “a great clot of genital fluid held in suspense or reserve,” stating, “I believe that the species changes as suddenly as a man makes a song
or a poem... It is not even proved that man is at the end of his physical changes.40 Pound had been trying to understand acts of creativity as the material outcome of body processes, particularly the capacity of humans through chemical impulses in the brain to detach from their corpus internal bodily tools such as the production of heat (from internal digestion to external fire): “All sorts of extravagances in nature may be taken as the result of a single gush of thought. A single out-push of a demand, made by a sea of sufficient energy.”41 In the wake of evolutionary biology, Pound acknowledges that aptitudes of auditory “genius” developed without physical change to the ear—“from the faculty of hearing four parts in a fugue perfectly, to the ear for money”42—and proceeds to speculate: “The ‘next step,’ as in the case of the male organ of the nautilus, is to grow a tool and detach it... Let us suppose man capable of exteriorizing a new organ, horn, halo, Eye of Horus. Given a brain of power, comes the question, what organ, and to what purpose?”43 However bizarre this and de Baer’s imaginative pressing on biological limits may seem, they were not alone for the period, and arguably make explicit what was implicit in the collective readiness to entertain Preyer’s ultrasonic claims. For his part, Pound regarded the idea of expanded sense capacity as normative in 1921—“lying on the study table of any physician or philosopher.”44

Leaving futurist speculations to one side for the moment, the debacle over higher pitch perception effectively marks the emergence of biosemiotics: the study of sensory signification within living organisms. The concomitant epistemology of sound based on sense acuity undermines contemporary doctrines of the ontology of art.45 After all, a flute sonata sounds—and at some level is—different for you before and after you might suffer hearing loss. Several recent theorists have sought to embrace this perspective: Mark Reybrouck redefined music simply as “a collection of sound/time phenomena which have the potential of being [mentally] structured,” where any meaning of heard music derives not from ontological categories but from a listener’s disposition to react to stimuli;46 and Gary Tomlinson’s concept of the “parahuman” listener emphasizes in part the extent to which listeners labor in acts of listening, actively participating in the creation of musical sound by setting “in motion the processes of signification” that define—in this case—the “techno-semiotic exchange” of Wagner’s operas.47

In effect, this definition of music has long been applicable at a cognitive level through the idea that the “music” a listener identifies with performance acts is highly dependent on the perceptual acts they are able to accomplish.48 “Like all communication,” Milton Babbitt argued back in 1958, theoretically complex music “presupposes a suitably equipped receptor.”49 But this is not easily reducible to a two-way street between sound object and listener. The radical theory at issue here sees musical
experience assessed not just cognitively, in this way, but sensorially—it becomes an affordance of the body, effectively created through the matrix of received stimuli generated by sense organs. This defines the limits of, as well as enables, the listener’s sonic experience (much like the Jena poets of Wackenroder’s generation felt constrained as their poetry “created the world” through the artificial grid of the German language). This is not to say that the emergent reality of music in the scientific age is nothing but sonic/somatic sensations, Massumi’s “prepersonal intensities,” only that material realities of sound have a bearing within an ecological approach to performance. Nor does it imply a return to frail ontologies—“the music itself” etc. Rather, it asserts that the concept of sensory acuity is formative for our subject identity in ways empirical as well as phenomenological.

In this article, I seek not only to substantiate existing moves toward an ecological theory of listening, but also to throw into relief the organizing frame of the body that such theories have relied upon. The history of debates over technology and the body raise questions about the authenticity of our perceptual means, the potential utility of sense augmentation, and the degree to which our identities (as listeners) may depend in a broader sense on the perceptual apparatus we control. This approach tends to regard sound as a material object, stripped of applied meanings, rather than a sign rooted in schemes of mimesis and representation. A turn of this kind toward materialist epistemologies challenges some of the basic assumptions that have underpinned our understanding of sound in recent decades, including perhaps even our “normative sense of the human and our belief about human agency” wherein performance and listening—practices forever in contact with sensible objects—beg a corresponding inquiry into how matter itself can animate and define experience.

Jakob von Uexküll

A touchstone for this approach to materialist epistemologies is J. J. Gibson’s theory of ecology, whose central thesis famously relates organism to environment, and whose unifying principle between disciplines has been “the question of what can stimulate a sentient organism.” Historically this view found expression in the fields of both psychology and theoretical biology in the decades surrounding the First World War. When, in 1923, Freud formalized his division of the psyche into Es (id), Ich (ego), and Über-Ich (super-ego), he identified the ego, the seat of our self-identifying conscious awareness, as “first and foremost a bodily ego.”

His footnote to the later English translation clarified that:
The ego is ultimately derived from bodily sensations, chiefly from those springing from the surface of the body. It may thus be regarded as a mental projection of the surface of the body, besides . . . representing the super-}

ities of the mental apparatus.\textsuperscript{55}

In fact, Freud was adapting biological research to “the mental apparatus”—much as Helmholtz had adapted physiological research to what he termed the “mental ear.”\textsuperscript{56} Fourteen years earlier the Baltic German biologist Jakob von Uexküll had effectively grounded Freud’s claim empirically in relation to cell structure. He argued that each sentient organism has a peculiar, limited sphere of perception, and that this exists in dialogue with the objects of that organism’s environment. His theory emerged a decade after Preyer’s claims of hearing 40,960 Hz had been overturned; it cries out for reinspection amid recent moves toward the listening subject. My interest here is to suggest the extent to which it relates disproportionately to contemporary understandings of sound and otology, and, as such, would become foundational for twenty-first-century debates over auditory prosthesis.

Uexküll introduced the concept of Umwelt to describe this bubble of perceivable space within which we live; it combines an individual’s Merkwelt (everything an organism perceives physically) and its Wirkwelt (everything it acts upon mentally or produces through the use of its perceptual tools). Another way to put this would be that it combines physiological limits with directed or learned perceptual attentiveness that abstracts some sounds—in the case of listening—in preference over others, a practice Jonathan Sterne recently conceived as “audile technique [that] problematizes the shape . . . [and] content of audile space.”\textsuperscript{57} These two elements, innate physiology and mental honing, remain conceptually separate for Uexküll. Acknowledging his nourishment on Kant,\textsuperscript{58} Uexküll effectively articulates a new noumenal realm: “The space that surrounds us is always bounded. We can perhaps imagine an unbounded space in our thoughts, but our sensory tools have no knowledge thereof. They teach us that we remain constantly surrounded by a bubble—breakable perhaps, but for us just as inaccessible as impenetrable.”\textsuperscript{59} Figure 2 presents the chain of signification schematically, using Uexküll’s terms of reference from 1920.

His main thesis, first set out in Umwelt und Innenwelt der Tiere (The Outer and Inner World of Animals; 1909), is that each sentient organism creates its unique environment by its capacity to receive only signals that register on its peculiar sense organs.\textsuperscript{60} Hence, these perceptual limits define the nature of all that is, materially speaking, for the organism. Uexküll’s classic example is the tick: blind and deaf, it smells the butyric acid of its prey, so knows when to jump onto the passing animal; the
Warm skin confirms this as a source of nutrition, and on sensing a patch of hairless skin, the tick begins boring for blood. It will feed only once before dying, so can neither learn nor refine the procedure.

Just as the tick’s concept of an environment relates to only three “perception signs”—smell of acid, detection of temperature, touch of skin—so our human environment is multiplied by the complexity of our sensory apparatus:

All animal subjects, from the simplest to the most complex, are inserted into their environments to the same degree of perfection. The simple animal has a simple environment; the multiform animal has an environment just as richly articulated as it is.61

Different “perception signs”—things that living animals notice—create the significance of different experiences of the same objective space: the night sky differs for an astronomer, a commercial pilot, a child dreaming, an astrologer, a poet, a UFO-spotter. In other words, the night sky does not exist as a fixed object. Nor does sound. For Uexküll, the animal-environment axis explains a familiar disconnect between different disciplinary approaches to sound: “The environment of a researcher of air-waves and of a musicologist show the same opposition. In one, there are only waves, in the other, only tones.”62 If the perspective of sound studies is weakening this divide today, Roger Scruton underscores its resilience by
emphasizing, in mirrored fashion, the incommensurability of perspectives from an acoustician who hears frequencies and durations and a music theorist who hears harmonic tension and voice leading in the opening theme of Beethoven’s Third Piano Concerto:

Each way [of apprehending what is heard] is cognitively complete—that is to say, it apprehends and orders everything that is there... The reductivist would argue that... the music is nothing but the sequence of pitched sounds, since if you reproduce the sequence, you reproduce the music... But to hear the music it is not enough to notice the sounds. Music is inaudible, except to those with the cognitive capacity to hear movement in musical space, orientation, tension and release, the gravitational force of the bass notes, the goal directedness and action-profile of melodies, and so on.

Uexküll’s musical reference—unwittingly elaborated by Scruton—is indicative of sound’s special capacity to draw attention to what the biologist called “constitutional differences” (konstitutionelle Unterschiede) between the environments of different people, to split apart simultaneous realities. For these differ from one another as a result of combining an individual’s sensory means of perception (the Merkwelt) with the actions, attentiveness, and habitual uses to which they are regularly put (the Wirkwelt). Examples are defensively qualitative, but the principle is clear:

Since the perceptual capacity of humans varies enormously, so their perceptual worlds [Merkwelten] must differ from one another. The individual human is connected to his environment not only by means of his sensory tools that enable him to notice [things], but also thanks to his actively used perceptual “tools” [Handlungswerkzeuge], which connect him to his effect world [Wirkungswelt]. Together perceptual world and effect world create the environment... The environments [of different individuals] are constituted so very differently that we can even speak of occupational worlds.

It would seem odd to ignore the applicability this has for different listeners witnessing the same performance. Different human environments are challenging for Uexküll to exemplify, but between species the parameters of variance concern the experience of time (speed of cognition), the sensible electromagnetic spectrum, sound frequency range, and spatial awareness. Uexküll’s visual illustration of a street scene perceived by a human, a fly, and a mollusk, given in figures 3a–c, is artful in its supposition, but may nevertheless be helpful as an ocular analogue to the varying “skill” of different listeners’ experience of complex music, envisioned by the likes of
Figure 3a. A photograph of a village scene, given in Uexküll, *Streifzüge durch die Umwelten von Tieren und Menschen* (1934), 26–27; Eng. trans. (2010), 64–65.

Figure 3b. The same scene visualized through the eyes of a fly, created by reducing photographic resolution against a fixed grid according to the number of visual elements in the fly’s eye.
Babbitt and Scruton. The hierarchy implied compares to the ranking of sentient organisms by their perceptual acuity within the single world of classical biology. By contrast, for Uexküll each organism’s relation to the environment is equally perfect, from amoeba to elephant, their perceptual worlds reciprocally exclusive and uncommunicating, corresponding as an ensemble to the world composed by the totality of its perceptive inhabitants. In the end, however, all matter within this totality remains unknowable in itself. Animals “never enter into relation with an object as such,” Uexküll concluded, which is to say all sensory relations remain representational.68

Musical Umwelten

Accepting Uexküll’s argument means accepting the existence of an infinite variety of perceptual worlds. Hence the task he set himself was speculative—to find a way of “thinking himself into” other perceptual worlds.69 Some musicologists have followed suit in the service of deconstructing the Western canon. Bruno Nettl adopted the same strategy when he hypothesized how “an ethnomusicologist from Mars” might listen
to Mozart, and Nicholas Cook recently crystallized the perceptual gains, positioning “Western music as world music.” As these illustrate, any strategy of distancing oneself is of course not exclusively physiological. (In answer to the question “What is it like to be a bat?” philosopher Thomas Nagel pointedly argued that materialist theories of mind omit what is essential to consciousness, that there is a state that it feels like to be a particular conscious thing, a subjective character of experience.) But physiologically, the direction of travel for any distancing operation is necessarily reductive, from greater to lesser acuity, as figure 3 demonstrates: humans with unimpaired sight could simulate color blindness but not vice versa, Uexküll explains; “[j]ust as little can the unmusical man conjure up the world of melody in which lives the man who has a musical sense,” he adds.

For skeptics, this amounts to little more than a metaphor for “getting outside yourself” and seeing another point of view. But a lateral glance reveals related intellectual enquiries during the early twentieth century, which help corroborate Uexküll’s theories as part of a broader impulse to destabilize the monopoly of human perception. Nietzsche, in disparaging the hubris of anthropocentrism in 1873, anticipated the singularity of an animal perspective in stark terms:

There have been eternities when [human intellect] did not exist; and when it is done for again, nothing will have happened. For this intellect has no further mission that would lead beyond human life. If we could communicate with the mosquito, then we would learn that it floats through the air with the same self-importance, feeling within itself the flying center of the world.

If this relativizes human perspective, Edmund Husserl massified it two decades later when he defined the aim of phenomenology as unprecedented “epistemological clarity” (erkenntnistheoretische Klarheit und Deutlichkeit) whereby philosophers were to hold their assumptions about the world’s existence in abeyance in order to reach a higher state in which they could analyze the contents of their own perception. The resulting state of heightened self-consciousness, the so-called phenomenological reduction, seeks unmediated perception, knowing the particular appearance of objects for “me” as such. Though distinct, both seek to interrupt perception and estrange customary associations—to break the spectacles through which we normally look at reality. If this often takes effect at the level of tactility (figured as the “interplay of the senses, rather than isolated contact”), here sensory labor is precisely the point: the linchpin around which a philosophy of materialism pivots.
Amid these developments it seems uncontroversial, methodologically, to argue that a musician’s perceptual “world” relates both to the art he or she produces, and his or her way of perceiving it. Writers of all stripes have interpreted known mental or physical conditions deterministically in this manner. A recent analysis of such determinism is given in Joseph Straus’s application of disability theory to the analysis of *Formenlehre* principles, where harmonic “abnormalities” in sonata form movements by Schubert and Beethoven become explicable by the disease and aberrant physical conditions of their composers. Such approaches are grounded in a theory of embodied cognition wherein individuals experience and interpret the world differently through the idiopathology of their bodies; correspondingly, everything from spatial metaphor to the visual spectrum is experienced as an interpretation thereof. Yet the point is rarely made that if the mind–body complex becomes a means of understanding music by deviation from a posited, problematic “normal,” the obverse was equally true: at the turn of the century, music was seen by some as a phenomenon uniquely suitable for studying the mind–body complex. Carl Stumpf’s two-volume *Tonpsychologie* (1883, 1890) set a precedent for positing musical sounds as the ideal material for scientific scrutiny of the mind: “Perhaps nowhere will the collected tools of psychological research allow for the same combination—self-observation and external data, statistical collection and data sets, physiological facts and hypotheses, comparison of peoples and times, biographical factors etc.” This interlocking condition suggests an emergent, special role for sound as a tool in the study of human perception at the turn of the century, one whose cultural work continues under the rubric of sound studies, but whose history has arguably been overlooked.

Given the influence of Stumpf’s beliefs and the subsequent tradition of connecting perceptual world and artistic production, it is surely no coincidence that music turns out to be central to Uexküll’s way of thinking. Indeed, his investigation is shot through with musical allusion. He uses musical paradigms—from the spatial organization of the diatonic scale to the perceived unity of individual works—to illustrate principles of cellular organization and function. It seems sounding music, as an invisible, apparently self-organizing phenomenon in three-dimensional space, provided him with a double analogue: for the unseen patterning of biological composition and for experiencing music and environmental sound in dialogue with that composition.

To take one example, Uexküll asks his readers to imagine a Russian choirmaster tasked by Peter the Great with imitating European choral music at court, but who is only able to draw singers from army...
ranks, where voices are untrained and often musically illiterate. To solve this problem each soldier is taught to sing only a single pitch irrespective of the stimulus he receives, so that the choir can be “played” like a pipe organ. Since multiple singers are assigned the same pitch, each note constitutes “objective energy” (a predefined frequency) but with subjective quality (it is performed by several individuals, what philosophers call joint collective action). Following this compound analogy in which each singer—primed to sing only one pitch—represents an organ pipe, which in turn represents a human cell, Uexküll concludes: “Our entire corporeal organization is built according to the principle of hearing and sounding organ pipes. That means we consist entirely of individual totalities, each of which possesses its own law.”

At first blush this serves as a check against materialism. “To find in the properties of living matter nothing more than the expression of a dance of atoms,” Uexküll remarked in 1930, “is not only to be hard of hearing but to be stone deaf.” Hence “melody” is the organizing principle for an organism’s cellular structure; the sensory stimuli an animal receives constitutes “rhythmically arranged melodies of impulses”; the process of cellular division arranges each body “into a resounding carillon according to a certain formative melody”; and “every organism... is a melody that sings itself.” What significance should we accord such analogies? As Derrida reminds us, verbal surfaces are not superficial: “Metaphor is never innocent. It orientates research and fixes results,” so it seems reasonable to ask whether there may be an anchoring effect at play, wherein the idea of music is creating a value for its position within Uexküll’s theory before that theory was formulated. We may never know, but the sustained metaphors lend credence to the view that a listening environment may be the theory’s purest exemplification, its natural telos.

II

Transhumanism and the Posthuman

If Uexküll’s achievement was to map the biological limits of each species schematically, the recent discourse of transhumanism calls these limits into question. Specifically, transhumanism regards biology itself as the limitation. “We extropians don’t want just to be normal,” futurist Max More exhorts, “we want to be supernormal, superhealthy, superstrong,
superintelligent." Of course, the technological context of the past few decades differs radically from that of Preyer’s ultrasonic pretensions and Uexküll’s Umwelten. Both espoused a reversible proposition we might extrapolate concisely as “sound defines human,” yet both also characterize a readiness to press at the physiological boundaries of what was understood at the time to constitute *Homo sapiens*. By contrasting this turn-of-the-century German discourse with Anglo-American affirmations of a transhuman subject a century later, I seek to demonstrate that despite differences of context and of certain framing epistemologies, a difference of technological capacity has not fundamentally altered attitudes toward the biological limits of sentient bodies. My second claim is that this discourse has previously played out, and continues to play out, in a conspicuously auditory context. As well as decentering a dominant visualist tradition in scientific hermeneutics, such an approach offers a historical foundation on which to reconsider the fundamental role of sound in understanding sense perception, what Stumpf back in 1883 dubbed “ensounding revelations” (*heraustönende* Offenbarungen) about human nature.85

First, a clarification of terms. A certain confusion haunts discussions of transhumanism, the posthuman, and posthumanism, each of which denotes a separate category. I cannot settle definitions for the array of disciplines implicated in this article, but a summary of my usage of the terms in the context of music and the humanities will be helpful.

In brief:

**Transhumanism**: An optimistic belief in the enhancement of the human condition through technology in all its forms.

**Posthuman**: The new condition attained after stages of technological enhancement render the subject no longer normatively “human.”

**Posthumanism**: A discursive web of philosophical positions defined against, and seeking to supplant, the autonomous liberal human subject and its concomitant anthropocentric bias.

*Transhumanism* (H+) encompasses a futurist-orientated intellectual and cultural impulse pertaining to human–technology relations, shared between the literary humanities, computer science, and the biomedical sciences. Its advocates believe in fundamentally enhancing the human condition through applied reason and a corporeal embrace of new technologies. It is rooted in the belief that humans can and will be enhanced by the genetic engineering and information technology of today as well as anticipated advances, such as bioengineering, artificial intelligence, and molecular nanotechnology. The result is an iteration of *Homo*
Sapiens that is enhanced or augmented, but still fundamentally human. Using devices to compensate for natural functions that have become deficient, for example wearing glasses or implanting a pacemaker, would not count as transhuman under such terms. To date, areas of change include natural aging (including, for die-hards, the cessation of “involuntary death”) as well as physical, intellectual, and psychological capacities. As such the tenets of transhumanism bear genealogical traces to earlier discourses of embodied identity and the machinic body, including notably Donna Haraway’s cyborg and its call to expose the production of universals such as Nature or human: “What counts as nature—a source of insight and promise of innocence—is undermined, probably fatally.”

A central premise of transhumanism is that biological evolution will eventually be overtaken by advances in genetic, wearable, and implantable technologies that artificially expedite the evolutionary process. This was the kernel of More’s founding definition in 1990, and Article 2 of the multi-authored “Transhumanist Declaration” (2012) continues to assert the point:

We believe that humanity’s potential is still mostly unrealized. There are possible scenarios that lead to wonderful and exceedingly worthwhile enhanced human conditions. . . . We favor morphological freedom—the right to modify and enhance one’s body, cognition, and emotions.

The very idea of such freedom illuminates Uexküll’s theory of Umwelt afresh. Now it would seem to emphasize how a totality of all perceivable existence remains beyond our sensory limits, the ontic nature of what is, philosophically speaking. Brushing against this postulate are technological prostheses that enhance our naked sensory knowledge, including sonic amplification, which appeared in the age of Preyer and Stumpf to offer privileged access to this ostensibly inaccessible realm. Anticipating later techniques of sonification, Alexander Graham Bell’s photophone sought to enable its users to hear the very burning of the sun, for instance, while advocates of the microphone claimed it allowed one to eavesdrop on the footsteps of a fly. But this hope for “metaphysics materialized”—as Abbate eloquently put it—ultimately reinscribes our perceptual limits. For prior to a transhumanist worldview, such technology could not reside within human bodies.

The posthuman is essentially a state of completed transhumanism, wherein one’s “basic capacities so radically exceed those of present humans as to no longer be unambiguously human by our current
standards,” in futurist Nick Bostrum’s words. Elsewhere he specifies the bar for entry as a being with “at least one posthuman capacity.” In its more radical iterations, this condition even does away with the biological body altogether, where information patterns uploaded to a fantastical supercomputer suffice to constitute a posthuman identity. In an extreme form of noetics, such existence becomes all mind, more powerful than present minds, employing “different cognitive architectures or includ[ing] new sensory modalities.” Despite advocacy from leading scientists such as Hans Moravec and Raymond Kurzweil, for non-converts such ideas reside squarely within the domain of science fiction.

Posthumanism, by contrast, is typically conceived discursively. It presents a range of philosophical positions that seek to supplant humanism, along with its attendant anthropocentrism, excessive valuation of human achievements, and preoccupation with humanity’s supposed differences from (and superiority to) the rest of animate life. The first explicit articulation of a modern posthuman worldview, Ihab Hassan’s article “Prometheus as Performer” (1977), inaugurated the discourse through the entertaining spectacle of a “University Masque” among eight symbolically humanistic characters, wherein his prediction that “five hundred years of humanism may be coming to an end” has become a touchstone. Indeed, while posthumanism has been overdetermined across media and scholarly contexts, its commentators consistently regard an autonomous, self-determining liberal human subject as no more than an idea with a traceable history. Posthumanist attitudes anticipate an increasing incorporation of artificial technologies into the body not primarily as enhancement of the human condition (as in transhumanism), but as its anticipated dissolution. This is seen as part of a more fundamental dissolution of literal boundaries between subject and object, body and environment, and a corresponding recalibration of our sense of self-identity within a world of objects.

Related theorizing under the rubric of “new materialism” opposes the separation between human and nonhuman environments, emphasizing instead the interrelatedness and interdependency of biological and non-biological forms of agency. This asserts no definite break between sentient and non-sentient matter in the relational fields of an environment because matter is no longer conceived as passive or inert, but capable of “self-transformation, self-organization, and directedness.” At the radical fringe, it is invested with agency that subsumes nothing less than human intentionality, freedom, and cognitive ability. The anticipated result is a move toward models of existence constituted by a distributed cognition, an identity accepting of non-biological thinking parts, one built on agency distributed non-hierarchically between animate and non-animate,
sentient and non-sentient parts, where the conscious mind becomes “a
small subsystem running its program of self-construction and self-assurance while remaining ignorant of the actual dynamics of complex sys-
tems.” The result is an identity defined ever more by its controllable ar-
chitecture rather than its cultural history.

In academic circles, posthumanism has repurposed scholarly trends
persuasively, rationalizing why, for instance, structuralist thought of the
late twentieth century was preoccupied with dissolving the subject, with
obliterating the hard Cartesian ego that distinguishes itself from the world
by turning the world into an object. “Man is an invention,” Foucault
remarks in the closing pages of The Order of Things, “whose recent date,
and whose nearing end perhaps, are easily shown by the archeology of our
thought.” That is, in this instance of posthumanist revisionism, the dis-
cursive networks of metaphysics and epistemology that had universalized
man and his history, notably during the Enlightenment, are revealed to be
increasingly parochial to a time past. Beyond the historicizing of gender
constructions, race studies have also co-opted the liberating tenets of the
debate to highlight what Alexander Weheliye calls an aporetic relation-
ship between “New World black cultures and the category of the
‘human.’” In both cases, “human” becomes a culturally and historically
specific designation. This explosion of antiquated canonical values helps
explain why, for the literary humanities, posthumanism is positioned as a
response to a perceived crisis: in Stefan Herbrechter’s words, “the crisis of
the last remaining metanarrative, namely humanist anthropocentrism,
and its origins.” By evacuating this traditional anthropocentric core,
and capping a more than five-hundred-year-old tradition of studia huma-
nitatis, discourses of posthumanism have emerged as a more radical branch
of humanism whose affordances are touted by commentators such as Rosi
Braidotti as a positive resource in countering a perceived malaise inhabiting
the humanities. Regardless of whether there may be a whiff of technol-
ological utopianism here, from an academic standpoint, it seems, the
discourse is self-consciously one of renewal and rejuvenation.

For present purposes, it is transhumanist hopes for enhancement
that bear on a listening ear in reach of ultrasonics. If automatic, material
communication was once epitomized by what Helmholtz called the
“material ear” (the mechanism of our inner ear when confronted with vi-
brating air; that is, sympathetic resonance), more recent listening practices
materialized through devices such as cochlear implants indicate that
“automatic” processes are central to the engagement between the ear’s
physiology and technology. Below, this materializing impulse is reassessed
under the rubric of a transhumanist discourse.
Origins of a Non-Human Ear

The idea of understanding the body as a communication matrix whose functions are refineable can be traced back to the Macy Conferences in cybernetics between 1946 and 1953, in which mathematician Norbert Wiener established so-called first-order cybernetics as “the scientific study of control and communication in the animal and the machine.” The origins of a posthuman worldview bear witness to the conceptual symmetries—human part:object part—that enabled this paradigm shift. Tracing it reveals afresh our current attitude toward bodies, and not coincidentally, this returns us one last time to the closing decades of the nineteenth century. In 1877 Ernst Kapp published his Grundlinien einer Philosophie der Technik (Principles of a Philosophy of Technology), a wide-ranging study of the effects on human society of the use of technology. In this text he coined the phrase “philosophy of technology,” and for this reason it is commonly cited as the originator of this field of inquiry. In his second chapter, Kapp argued that tools and technologies are projections of human organs: the eye is the model for the camera obscura, the teeth provide a formative image of the saw, the forearm with clenched fist does the same for the stone hammer, the crooked finger becomes a hook, etc. Such relationships, as Kapp puts it, constitute “a projection of organs or the mechanical after-image of an organic form.” The ear does not escape Kapp’s purview; he saw the vibrating hairs of the cochlear duct as a biological model for both the overstrung piano and the wind harp, that most natural and automatic of instruments.

But two aspects of Kapp’s projection of organs need to be separated. On the one hand, he is concerned with technological genesis, in which the technical means are seen as unconscious “after-images” (Nachbilder) of human organs. On the other hand, he thematizes the cultural dimension of technology, wherein this technical means is posited as a medium through which we recognize ourselves. Herein lies the conceptual pivot toward transhumanism. For though the natural human body is primary for Kapp, and the technological “after-image” secondary, media theorist Friedrich Kittler grittily reversed this relationship in his pathbreaking analysis of human referentiality in media for communication and data storage, arguing in 1986 that media technology is a primary constituent of identity, the body its conceptual copy. “So-called man” was now the secondary product of technologies that are conceptually prior.

If Marshall McLuhan had already envisaged media in 1964 as prosthetic extensions to the human sensorium, Kittler went further. He effectively envisioned a feedback loop between technical and cerebral data-processing operations, wherein the one models the other with scant regard...
for the difference between computer circuits and human biology. Or, as he puts it, “Sensory aphasia (while hearing), dyslexia (while reading), expressive aphasia (while speaking), agaphia (while writing) bring forth machines in the brain.”¹¹⁰ When the technological differentiation of media channels—optics, acoustics, and writing—broke the monopoly of alphabetic writing ca. 1800, he continues,

the fabrication of so-called Man became possible. His essence escapes into apparatuses... Machines take over the functions of the central nervous system, and no longer, as in times past, merely those of muscles. And with this differentiation... a clear division occurs between matter and information, the real and the symbolic... So-called Man is split up into physiology and information technology.¹¹¹

At a minimum, Kittler is saying that the emergence of analog media in the late nineteenth century is fatally tied to similar advances in the analysis of human cognition and perception. Subsequent theorists have taken a harder line, but his unrelenting focus on data streams obliquely highlights the “clear division” he asserts “between matter and information.”¹¹² This division would underpin a landmark study fifteen years on, Katherine Hayles’s How We Became Posthuman (1999), which seeks to undo the concept of embodiment, or rather, to define a human being “first of all as [an] embodied being.”¹¹³ For Hayles the central move posthumanism makes is to separate information from its body, like an apparently amorphous blob of a shellfish plucked not from its structuring exoskeleton but from its genetic data. Information in the form of data patterns become the ultimate, indispensable reduction of meaning, beyond which no further substance inheres. (To be sure, pushback against this infatuation with data/information as units of identity has a parallel history,¹¹⁴ just as the desire to exceed our biological limitations stretches back at least four millennia, and for this reason might be considered fundamentally human.)¹¹⁵

After asserting the posthuman “privileges informational pattern over material instantiation” where consciousness constitutes “an epiphenomenon... an evolutionary upstart,” Hayles characterizes the posthuman’s remaining tenets accordingly:

Third, the posthuman view thinks of the body as the original prosthesis we all learn to manipulate, so that extending or replacing the body with other prostheses becomes a continuation of a process that began before we were born. Fourth, and most important, by these and other means, the posthuman view configures human being so that it can be seamlessly articulated with intelligent machines. In the posthuman, there are no essential
differences or absolute demarcations between bodily existence and computer simulation, cybernetic mechanism and biological organism, robot technology and human goals.\textsuperscript{116}

By viewing prosthesis as part of an ongoing evolutionary process, from the blank canvas of a congenital body onward, the third and fourth tenets remain fundamentally anthropocentric; and ultimately Hayles doesn’t subscribe to them. Why? Because the history of biological evolution cannot simply be eradicated by devices of artificially intelligent listening/sensing/cognizing, regardless of whether the body is considered primary (Kapp) or secondary (Kittler) to technological tools. It is incarnated with a sedimented history, Hayles explains: “a physical structure whose constraints and possibilities have been formed by an evolutionary history that intelligent machines do not share.” For this reason, humans may enter into “symbolic relationships with” or be “displaced by” intelligent machines, she concludes, but the discursive difference between machines and humans in their embodiment means “there is a limit to how seamlessly humans can be articulated with intelligent machines.”\textsuperscript{117} For present purposes, this postulated limit point is exemplified by the case of auditory prosthesis and augmented auditory sensation, to which we now turn.

**Musical Listening and Transhumanism**

So what is at stake for a theory of musical listening? We have already seen that individuals reside in empirically different perceptual worlds. Transhumanist attitudes destabilize the idea that an individual inhabits a singular Umwelt. If even the biological given of our bodies becomes potentially changeable, what multiplied complexities would result for our perception? Meaning would no longer be guaranteed by a coherent origin in the (purely) human body. How would this affect music aesthetics? Aesthetics itself—as the (human) study of the beautiful—may no longer even be applicable.

Amid such alarm, possibilities also lurk. To date, music-orientated discussions of transhumanism and the posthuman have focused principally on simulations of the human voice as signifier of human/cyborg identity.\textsuperscript{118} Moving beyond this, the music potentially implicated is numerous and varied. It incorporates algorithmic composition and artificial intelligence, music generated by somatic feedback\textsuperscript{119} and data audialization in general, as well as machine-led musical training, computer-aided performance of complex music, and the imitation of inhumanly complex sound configurations that occur in nature (such as the irregular rhythm of pedestrians on a bridge or the polyphony of beating wings as a flock of pigeons takes off).
In a material theory of communication, the ear—unclosable and inert—is perhaps the most profoundly implicated sense organ for theorizing historically the limits of human sensation. Hence I delimit the remainder of this article to developing the material theory of listening with which we started, and music conceived in relation to auditory thresholds.

Musical sounds situated at the boundaries of our sense perception play on Uexküll’s theory of Umwelt. When the ear is no longer restricted by biology and becomes a site of potential technological augmentation, the very idea of normal auditory perception becomes inherently vulnerable; it follows that what is at stake in the dance with technology is nothing less than sound as music. Two examples can help to ground this bold claim.

**Our Sonic Umwelt 1: Sciarrino**

In 1979, the Sicilian composer Salvatore Sciarrino (b. 1947) advanced an explicit manifesto that future developments of modern music should investigate “the boundaries of auditory perception.” Music itself is the medium *par excellence* for cultivating an aesthetic of perceptual limits, he asserts:

> Music inhabits a threshold region. Like dreams, where something both exists and does not yet exist, and exists as something else as well. And where these sensations, the most fleeting of them, cross the threshold of unconsciousness with the blink of an eye: outside, they are prolonged, sharp and clear, having survived the passages from drowsiness. These are the sounds found close to the horizon of the sense.

Sciarrino’s *Sei capricci* for solo violin (1976) play on a very particular “horizon of sense,” the threshold of audibility, including both upper frequencies and minimal sound intensity. Though this fact cannot circumscribe the sum value of *Sei capricci*, I would like to explore the claim that the six caprices, distantly modeled on Paganini’s Opus 1, can be read as transhumanist for reveling in human limits, for pushing beyond our natural capacity, sensory as well as technical. It is a fitting genre for transhuman exploration because, historically, the roles and activities of the virtuoso reside within a set of paradoxes, one of which is the contradictory embodiment of human and other. The tension between the identities of mechanical executant and inspired supra-human leave unspecified the origins of the non-human agent. Just as certain early nineteenth-century listeners accepted that Paganini was possessed by the devil because of his uncanny mastery of his instrument, so the virtuosity and de facto...
unrealizability of Sciarrino’s late twentieth-century caprices potentially invoke the need for extra-human means.

Situated in the instrument’s uppermost range, the six caprices utilize artificial harmonics almost exclusively (producing distortion, in contrast to natural harmonics). They outline a fragile tissue of sound that—in the present context—can function as a metaphor for the fragility of our perceived reality itself. The notation indicates where to place fingers on the fingerboard rather than a sounding pitch; the resulting pitches depend on how firmly the finger depresses the string and any distortion produced from the bow contact, hence it is illegible for the purposes of silent reading (the historical archetype for which is surely Brahms’s comment on reading Don Giovanni in 1887). Unlike traditions of nineteenth-century virtuosity, the totality of these works remains genuinely unplayable and inaudible as written; the artificial harmonics resulting from Sciarrino’s extended techniques are effectively indeterminate distortions whose configurations on the fingerboard do not fit under the ordinary human hand. The playing techniques themselves draw attention to the artificiality of producing musical sounds. The rapid switching between *tasto* and *ponticello* in No. 3 is typical in foregrounding the bow-as-medium, producing almost pitchless noises as the hairs brush against the string. A transhuman reading would see the (prescriptive) notation as a challenge to biological limits: by ensuring a performer deals in the residue of musical materials rather than in musical pitches as such, it becomes less a critique of notation, more a threshold aesthetic that goads us with what we cannot quite perceive and cannot quite execute.

At the level of notation, the first caprice is modeled on Paganini’s E-major caprice (No. 1) in its brilliant rising and falling ricochet bowings across broken chords. This texture is interrupted by a chromatic glissando figure, either ascending or descending, that co-opts the broken chords in sequences of between six and twelve chordal iterations. There are seven such “glissando interruptions” in total. As example 2 shows, the first of these uses the perfect fifths of the violin’s open strings, though later interruptions deviate into sixths and sevenths. The highest notated pitches are beyond the auditory threshold of musical pitch: g-sharp (just beyond the 88-key piano) occurs five times. Its sounding frequency is 6,644.876 Hz in equal temperament, but the likely pitch of its harmonic is d-sharp (19,912 Hz), which, if detected at this sub-PPP level, would be perceived as infinitesimal noise: what Helmholtz in 1863 called sensations (sense impressions we become conscious of only as conditions of our body, especially of our nervous apparatus) as opposed to perceptions (sense impressions from which we form a mental image of an external object). The same strategy is revisited in more truncated fashion at the close of the fifth
caprice, which proceeds into upper auditory limits through a rising harmonic on the G string marked: “Glissando without tightening the hand position! Until the end of the string!” This is given in example 3.

But as the data in figures 4a and 4b show, according to the American National Standards Institute, Sciarrino’s d-sharp at 19,912 Hz, played sub-PPP, is officially inaudible for humankind. As such, the ascending glissandi effectively mimic a threshold test, not unlike those of König, Stumpf, and Preyer, ca. 1890, probing the correlation of sound pressure (volume) with frequency (pitch).

Frequency and sound pressure are of course interdependent parameters, and each of the glissandi in Sciarrino’s first caprice begins and ends with silence framed by minute dynamic increments. As example 4 shows, two-thirds of the way through the work the opening broken chord is simply repeated seven times at different dynamic levels while a crescendo/diminuendo frame the passage in silence; it is a kind of intensity test, as though a messa di voce were being extended into the lower dynamic threshold. It presents an artistic vision of music hovering between what Aristotle called actual and potential sounds. Perception of actual sound requires “a certain form or power in a magnitude.” The need to control magnitude at the upper extreme is commonly understood; it helps us understand why excessive stimulations destroy the organs of sense:

If the movement set up by an object is too strong for the organ, the form which is its sensory power is disturbed; it is precisely as concord and tone are destroyed by too violently twanging the strings of a lyre.

Sciarrino’s music resides at the opposite end of the spectrum—too delicately “twanging” the strings for human perception. If our auditory system cannot detect sound being produced, it becomes “potential” sound, philosophically speaking, and a politics of posthuman difference deals precisely in “potential becomings that call for actualization.” That is, actualizing
Example 3. The rising glissando that closes Sciarrino’s fifth caprice. Copyright © 1976 Casa Ricordi S.r.l., Milan, Italy. All rights reserved. Reproduced by permission of Hal Leonard MGB S.R.L.

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<tr>
<th>Frequency (Hz)</th>
<th>Binaural listening, free-field (dB, SPL)</th>
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<tbody>
<tr>
<td>125</td>
<td>22</td>
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<tr>
<td>200</td>
<td>14.5</td>
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Figure 4a. Audibility threshold for binaural listening in a free field given by the American National Standards Institute; specification for audiometers. It shows the response of individuals listening to pure (sinusoidal) tones through speakers, using both ears while facing the sound source at one meter’s distance. The measurements, between 125 Hz and 16,000 Hz, are the accepted standard for human hearing tests and instrument building.

the potential, or what Salomé Voegelin calls the possibility of the “sonic impossible.” But to reiterate an earlier question: what kind of listener does such music imply?
To say the music resides at the extremities of sound itself is also to say it depends on the listener’s perceptual apparatus, the Umwelt they create. For there can be no concept of silence, in the sense of what cannot be heard, without limited auditory perception. Sciarrino explores the spectrum between silence and sound, but the poles are not absolute, biologically speaking. The composer himself cites auscultation to deny the existence of silence, where heartbeats and breath remain audible in any sealed chamber: “As long as one is human there is no silence: and where there is perception, there is music.” We tend not to adopt a transhuman position that sees the physiology of listening as a performative factor in this context. “Is there a metaphysics of silence?” Sciarrino asked in 1990:

I don’t know. . . . Certainly silence, a “zero-sound” . . . presents unsuspected theoretical problems. How does one decide the frontier, the point of
passage? There is a sort of reversal in my music, in that the sounds preserve traces of the silence from which they come and into which they return, a silence which itself is an infinite rumbling of microscopic sonorities.  

Here, silence becomes a word for sounds for which we have no ears. And Sciarrino’s bridging of sound and silence arguably implies a desire to hear into what is ordinarily silent, what is ordinarily beyond human nature.

In the end, this approach may seem reductive: a merely biological-scientific reading of musical listening, voided of the cognitive activity of expectation, fulfillment, denial, and patterning that we identify with musical experience. An alternative, transcendental interpretation is to hear the music melting into a noumenal realm, one increasingly inaccessible without technological assistance. Sciarrino’s caprices effectively make art by ensounding this process.

Our Sonic Umwelt 2: Nørgård

If these caprices inhabit a threshold region, other works categorically exceed it. Composed between 1986–90 for Danish Radio (and revised in 1991), Per Nørgård's Fifth Symphony is a single-movement work lasting thirty-five minutes. It requires six percussionists and a battery of high-pitched percussion, including mouth sirens, Peking Opera Gongs, sleigh-bells, metal chimes, swanee flutes, and ultrasonic dog whistles. The music explicitly plays with our lens of perception, as Nørgård recalls:

> What has fascinated me in the Fifth Symphony is the way a particular hearing range is made possible to our imagination as something analogous to what we see in our surroundings—where we usually see only one side of things. Our imagination is therefore already attuned to the fact that we see in parts, so why should this not apply to our listening experiences too?  

Like Uexküll thinking himself into other perceptual worlds, the hope here is that imagining other auditory ranges encourages us to accept the existence of other environments, what Voegelin has called the “aesthetic inaudible”—what is imagined to exist as sonic materiality but for which we lack the “sensibility, will, and wherewithal to hear.” If this comparison of visual and auditive regimes appears insufficiently critical, it arguably finds a more stable footing through empirical research: recall Rudolph König's visualization of sound at 90,000 Hz (see fig. 1), and the “deceptive . . . signal transductions such as the imaging of ultrasound” that create images from time-based sonic articulations far above human hearing.
Musically, Nørgård’s symphony presents geyser and avalanches of pitched sound that ascend into inaudibility then descend to muffled timbres of muted double bass and bass drum. Whereas previous ascents had risen to the uppermost register of the three piccolos, supported by rising glissandi in the harp, glockenspiel, and piano, Nørgård’s sound images hover above human thresholds through the use of two dog whistles at the apex of the highest ascent. In such a context, they literalize the poetic metaphor of inaudible music. As example 5 shows, two such whistles are blown ff and the resulting difference tone is intended to be heard. 135

What is inaudible in such passages cannot advocate the morphological freedom sought by transhumanists to hear higher frequencies. But it raises the question, even if the symphony’s play with thresholds of auditory sensation could just as easily be viewed as reliant on biological limits as protesting against them.

Promethean Dreams: Expanding the Auditory Range

As noted above, transhumanism’s embrace of morphological freedom—“one’s right to one’s body”136—includes augmenting our auditory system: replacing some of our biological apparatus with prostheses, the better to connect to other sounds, including Sciarrino’s and Nørgård’s music. Self-identifying transhumanists such as Anders Sandberg and Max More have already broached a range of ways in which to augment or “enhance” the biology of living people, and companies such as Cyborg Nest and Cochlear® are marketing artificial senses. 137 More, in an audacious “Letter to Mother Nature,” explicitly seeks an amendment to the human condition in these terms: “We will expand our perceptual range through biotechnological and computational means. We seek to exceed the perceptual abilities of any other creature and to devise novel senses to expand our appreciation and understanding of the world around us.”138

Counterintuitively, musicians may already have an affinity with this impulse. Theorist Mark Reybrouck once argued that it is in the nature of composition to push beyond perceptual limits, that composers construct an “internal model” that allows them to “go beyond the constraints of perceptual bonding and to carry out mental operations on virtual elements.”139 That is, where the reality of sensory input is impossible, it is replaced by representation and the universe of a symbolic order. But new sensory input is critical, as Reybrouck acknowledges. This need not imply the improbable growth of antennae, sensitive to hitherto unnoticed tremblings in the ether, as Pound imagined in 1921, and de Bear quantified in 1860. Changes to our auditory reality already occur in those who suffer
hearing loss; and following this logic, augmenting unimpaired hearing need be no different in principle to correcting impaired hearing.  

But there are two problems with this: first, that it may be impossible; second, that few if any medical professionals have asked the question before, and hence no empirical research into this field has been funded. It is indicative that a recent article for the World Economic Forum predicts five human enhancements that “could be commonplace by 2020” but makes no mention of the ear; the skin, vision, memory, and decision making assume priority.  

There is nevertheless evidence that existing technologies provide the means by which ears may potentially become sensitive to sounds below 20 Hz and above 16–20,000 Hz. These include:

- **Transposing algorithms** would shift frequencies from above 16,000 Hz to a perceivable range, in just the manner a hearing aid operates for individuals who may have “dead regions” in the cochlea. The bandwidth in high-end hearing aids can produce effective gain up to about 10,500 Hz, though most stop at 6,000 Hz (g””). Shifting frequencies distorts the sound, however, so this is currently a poor option for music.

- **Cochlear implants (auditory nerve)** would use a potentially enhanced speech processor capable of transposing an extended range of sounds, and which is connected to the auditory nerve, though the limited signal channels of implants were not designed for the spectrum-rich sounds of music, and the transposing algorithm again results in considerable distortion. In response, work to mitigate this effect through compositions adjusted or written specifically for cochlear implant users is tentatively underway.

- **Cochlear implants (brain stem)** would use a similarly enhanced processor, but connected directly to the brain stem, bypassing the auditory nerve by inserting iridium microelectrodes into the stem. The problems of distortion and a limited signal channel also remain valid here.

- **Bone conduction** of ultrasonic frequencies is possible using a piezo-electric “buzzer” (a piezo disc glued to a metal disc). Methods of ultra-high audio-frequency stimulation are typically used in treatment for tinnitus where residual neuronal function exists in the range 10–14 KHz, or for absorbing medicine through the skin. Ultrasonic frequencies become perceptible via bone conduction only with much higher sound pressure levels (typically between 80 and 100 dB for a sound at 8 KHz), with data indicating that no absolute threshold operates for this method. Though bone conduction fulfills the criterion of sensing ultrasonic sound frequencies, it offers mere buzzing, with no way of receiving meaningful sound communication, as in speech or music.
Cilia regeneration in stem cell and gene therapy can be used to repair damaged structures of the auditory system, where the principal focus has been regenerating hair cells (cilia) within the cochlear duct. The possibility of engineering organic hairs sensitive to ultrasonic frequencies cannot be ruled out. For advocates, such methods represent “the future treatments for hearing loss” but at present such treatments are “years if not decades away.”

In all but the last case, the degree of signal change (distortion) introduced to sounds received is so considerable that the methods initially appear non-viable for music.

Phenomenologically, however, this simply transforms vibrations into electrical impulses in a different way to that which occurs naturally in the auditory nerve; in this sense, it is only a different kind of sonic representation, or virtuality. For writer and implant wearer Michael Chorost, there is nothing inherently truthful about sensory organs’ representation of the universe: “Reality is ultimately a matter of software” he argues, “people with normal ears are not off the epistemological hook, because their ‘software’ was written haphazardly by millions of years of evolution and has no greater claim to reality.” As Mara Mills has shown, signal processing within the auditory nerve has been researched through patient response since 1957, and continues to be “the major site of cochlear implant development today.” She foregrounds Graeme Clark’s work on implant processors during the 1970s, wherein he explicitly took decisions about what elements from the sonic environment to filter into coded signals for the auditory nerve; prioritizing speech led him to seek “a more limited number of stimulus channels [that would] still adequately stimulate the physiology,” as he puts it, and to extract “only the essential speech information that can be processed by the auditory nervous system.”

Music was simply deemed less important than speech for those early patients seeking to go about their daily lives, but implants could equally well be optimized for music. For Mills, the selected competencies of such processors are “political” to the extent they encapsulate a “range of cultural and economic values . . . deliberately ‘scripted’ into the design.” Apparatus for other sense modalities, such as the “hearing glove” (attributable to Norbert Wiener), which stimulates the finger of a deaf person with electromagnetic vibrations, or the implanted color sensor that—for its color-blind recipient, Neil Harbisson—converts the color spectrum into sounds, including ultraviolet and infrared signals, present comparable instances. As do the media through which humans increasingly hear or otherwise “tune in” haptically to auditory vibrations underwater, from oceanic recordings to the Wet Sounds Festival. Technology transforms
signals for perception, in other words, and all sentient signals operate through analogy in this sense, which is why Hayles can plausibly summarize the principle historically, via the founder of cybernetics: “For Wiener, analogy was communication, and communication was analogy.”

Turning from the abstract to the concrete, Eisuke Yanagisawa’s CD *Ultrasonic Scapes* (2011) offers one illustration of ultrasonic analogy. His frequency-modulated field recordings of bats, cicadas, and streetlight drones transpose a motley array of sounds from beyond our auditory threshold. As indicated above, this technology could be adapted to hearing aids or implants, giving the wearer a positional advantage over “normal” listeners. Yet two potential flaws in the proposals above are: (1) the overlaying of transposed sounds onto those perceived “naturally” at target frequencies, leading to a new challenge of streaming auditory input simultaneously from multiple sources; and (2) the tonotopic mapping between the cochlea and auditory cortex. That is, specific nerve fibers of the cortex have evolved to be most sensitive to specific frequency inputs from the specific cilia hairs of the inner ear. This spatial correlation between perceiving brain area and stimulated cochlea area implies that the range of sounds we recognize as sound is limited by an interdependence of the auditory cortex and cochlea, not by the latter’s physiology alone. One implant wearer frames any changes to this in terms of an insurmountable learning curve: “I probably get more total information from the implant, because it triggers nerve endings that hadn’t had hair cells before. But I’m limited by having an auditory cortex that’s not developed enough to use the additional information.” While further research would be needed to begin to draw conclusions on the matter, brain plasticity is a proven characteristic; if the brain receives unfamiliar auditory stimuli, it would almost certainly adapt to accommodate those stimuli, which is to say new stimulation would drive change in the auditory cortex over time. For some, this may epitomize an expedited evolution, but the challenge of educating users to make use of any new sense capabilities remains indeterminate. At this stage, then, the idea of auditory sense augmentation amounts to little more than a thought experiment, one in which, for skeptics, “music” in the strong sense would have nothing to gain.

Current futurist predictions for cochlear implants in non-disabled listeners bypass aesthetics altogether, focusing on applications for the military and information-intensive business. Admittedly, Yanagisawa’s transposed sounds are but irregular crackles and blips. To imagine such sounds in opposition to familiar music immediately makes us opponents of the idea, as per reactions to Stockhausen’s compression of a Beethoven symphony into half a second—“then you have a new sound”—or to Dustin Carr’s music for a microscopic guitar where strings fifty nanometers
thick vibrate at 10,000,000 Hz, both unplayable by human fingers and inaudible to human ears. More broadly, the implications of virtually extending our Umwelt are unknown. Such an extension may be intriguing but appears at present unnecessary and potentially undesirable: it has an uncertain aesthetic claim, serves no current utility, and—in the extreme instance of surgical alteration—may be unethical. Critics of the view that “morphological freedom” is a basic right cite the need for protection from any such coercive biomedicine. Were established musicians to adopt a postulated surgical auditory extension technology, it may pressurize others to do likewise. As Isaiah Berlin once put it: “Freedom for the wolves has often meant death to the sheep.” There remains, then, an unanswered question about why such an innovation would be desirable. But such hesitation need not shut down further discussion. After all, wearable hearing aids and headsets can simply be taken off. On the one hand, any advocacy of auditory augmentation would need to respect the preferences, autonomy, and sensibilities of listener choice; but on the other hand, the unrealized possibilities implied by transhuman discourse bear open-mind consideration.

Stelarc’s “Extra Ear”

As is well known, prosthetic extensions of our senses already exist, and not all answer a perceived disability. In 1964 Wiener, the founder of cybernetics we encountered earlier, predicted a “new engineering of prostheses” involving mixed systems of both human and mechanical parts that “need not be confined to the replacement of parts that we have lost. There is a prosthesis of parts . . . which we never have had.” The postulate of a modified ear is clearly within such parameters. And there is no need to tamper with existing ears. In 2007 the Cypriot-born Australian performance artist Stelarc (a.k.a. Stelios Arcadiou) began a series of three surgical procedures to insert a soft prosthetic ear into his left forearm. The result is given in figure 5. Far from an act of replacement, this no longer replicates human hearing as such. As conceived, the Extra Ear’s purpose is not merely to receive new acoustic signals, but additionally to transmit them. A miniature microphone was initially implanted within the ear and functioned for two weeks as a means of transmitting sound signals via Bluetooth to an external device: “The [surgeon’s] voice was clearly heard and wirelessly transmitted.” It worked briefly, in other words. But a subsequent infection meant the microphone had to be removed; to date it has not been reimplanted.
It is tempting to read the remaining shell of an ear as subdued, an object of forlorn silence, a testimony to the inevitable collision between transhuman optimism and recalcitrant physiology. But ongoing commercial ventures point to this as an advancing frontier. Emphasizing enhanced connectivity, Apple and Cochlear’s joint processor Nucleus 7 (2017) connects compatible implants directly to the audiovisual services of Apple’s mass-market devices, meaning that digital auditory data are transmitted wirelessly to a surgically embedded implant without the need of a functioning congenital ear. Current advertising speaks of enhancing the experience of “talking on the phone . . . enjoying music or watching videos, as well as audio apps.”166 If this constitutes “the first mass market cyborg enhancement,”167 Stelarc likewise envisages reimplanting a microphone.

in his third ear to enable a bespoke, “wireless connection to the internet, making the ear a remote listening device for people in other places. For example, someone in Venice could listen to what my ear is hearing in Melbourne.” The speaker and receiver will not embed microelectrodes into the brain stem or auditory nerve, a prospect certain to affect the artist’s biological hearing. Rather they are to be placed inside his mouth, creating the illusion for Stelarc that the voices received are in his head, while offering the possibility of sharing the sounds with others by opening his mouth in a kind of vicarious speech: a displacement that literalizes the rhetorical technique of prosopopoeia. The decision not to embed into the stem or auditory nerve is not addressed in Stelarc’s writing on the project, but marks a limit for performance art that pauses at the prospect of irreversible neurological change. “I have 2 good ears to hear with,” he explains.

The consistent preoccupation with the body’s obsolescence in Stelarc’s work is perhaps unsurprising; it typifies a certain strain of activist futurism, or “body hacking,” at the sharp edge of the transhumanist debate. As early as 1982, when Stelarc was thirty-six, he declared the body an evolutionary fossil in need of technological complement. By 1991, the tone was unapologetic in its provocation: “It is no longer a matter of perpetuating the human species by REPRODUCTION, but of enhancing male/female intercourse by human-machine interface. THE BODY IS OBSOLETE.” His projects reflected this outlook. Prior to the third ear project, he devised “Third Hand” (1980) in collaboration with engineers at Waseda University and the Tokyo Institute of Technology. A robotic arm, mounted on his forearm, could be manipulated by electromyography signals from his abdominal muscles to draw letters. Detailed discussions of the project have appeared elsewhere. For present purposes the iconic image of the three hands writing “evolution” in 1982, shown in figure 6, captures at once the stubborn alterity of wearable enhancement technology, while inscribing the need for harmony and synchrony between “parts” in any claim for a transhuman evolution. This image constitutes but a momentary semblance, however, for it is only with the surgical permanence of the third ear that Stelarc’s performance art begins to tip into the category of morphological enhancement with its uncertain claims toward evolutionary change.

By dissociating one’s self from a biological body, self-identity becomes the lost referential, Freud’s “bodily ego,” and it may be no coincidence that, in a performance as early as 1970, Stelarc explicitly modeled the basic question Uexküll asked of Umwelt theory—whether it is possible to experience the perceptual world of other organisms—by donning a
A helmet designed to scramble binocular vision, superimposing fragmented rear and side views onto the usual frontal view in an attempt to replicate for his two eyes the compound eye of the insect. The Extra Ear accomplishes a similar task but its environment is the transhuman (enhanced body) rather than the non-human (insect), though both result from a drive to alter the body’s architecture, thereby “adjusting and extending its awareness of the world.” While this does not yet include transposing algorithms or implants for accessing ultrasonic ranges, it theoretically could.

In the end, the Extra Ear along with existing devices for sensory augmentation from the sphere of virtual reality can inform our estimate of how auditory frequency augmentation might effect musical perception. The materialized twittering blips and scratchy white noise of Yanagisawa’s Ultrasonic Scapes elicit no auditory pleasure bound to familiarity, form, or harmonic proportion. As such we would not judge them aesthetically beautiful, though the inappropriateness of measuring such noise against nineteenth-century aesthetics is old. As Eduard Hanslick put it in 1854, the scraping of a knife on glass conveys “the physical effects of sound waves, which pass along to the other nerves through the auditory nerve. . . . But this is not music.” Accepting this, access to fuller materialized sounds within our environment would nevertheless empower our sense of place, and push against our limitations regarding “the ontic nature of
what is." There would seem to be a certain pleasure in that. So at this ini-
tial stage, one of hypotheses and thought experiments, the pleasure of
extending the range of hearing is best regarded as a kind of virtual play: a
game of giddiness, of looking over the edge, hearing the hyperreal
heights—îlînîx in Roger Caillois's classification. By altering perception,
pleasure is no longer only that of haptic or aesthetic manifestation (seduc-
tio), but becomes sheer fascination and psychotropic distraction
(subductio).176

Epilogue: Naked versus Mediated Sound

When in 1876 Wilhelm Preyer believed he had proven the natural audi-
bility of sounds at 40,960 Hz, Helmholtz was glad of the gain in perceptual
reach but expressed dismay at the idea that such unmusical sounds were
now part of human physiology. If each nerve fiber registers its own pecu-
liar pitch, he remarked, “we should have to regard the auditory cilia as the
bearers of squeaking, hissing, chirping, crackling sensations of sound, and
to consider their reaction as differing only in degree from that of the co-
chlear fibres.”177 The noises were not imaginary, la domaine de la fanta-
sie.178 Preyer and Helmholtz’s ears did hear these actual sound sensations,
but at a frequency closer to 11,000 Hz. As we have seen, such sounds—
conceived as auditory reality defined by the listening subject—are not
atechnological. By hypothesizing the extension of our auditory threshold,
we are confronted with the realization that our relation to music hitherto
depends in large part on the limitation of what transhumanists would call
the “home” body, and what Uexküll theorized as our Umwelt—the recip-
rocal interchange between innate physiology and habitual use. Here ultrasonic
function merely as an index for the material limits of the body.

While enhancement is palatable as a check against debilitating medical
conditions, it also raises heady questions about subject identity in an ongo-
ing dialogic between body and prosthesis.

On this basis, I propose the need for a new, categorical distinction
between naked and mediated sounds. Between unamplified acoustic
sounds we hear without any form of electronic mediation, and sound that
is artificially converted into electrical signals before we experience it as
sound. Naked sounds are auditory vibrations converted into electrical sig-
nals within the congenital ear, such as listening to the rain thundering on
your roof, unaided by devices; mediated sounds are vibrations transformed
into an electrical signal at least once before reaching the inner ear (or
transformed artificially, via an implanted processor), whether in signal
transmission, amplification, distortion, or other processing operation. We
already fetishize such distinctions in controversies over “live” music,
simulcasting, and discrete amplification. But such distinctions rarely matter in experiential terms. Rather than privileging the congenital body as such, then, the purpose of such a distinction is to clarify a historically human identity for the perception of sound in light of emerging enhancement technologies. That the vast majority of sounds and popular genres we encounter are electronically mediated under such terms indicates just how fluid our relation to the auditory environment is. The concept of naked sound offers a means of anchoring this relation to our biology amid ongoing technological change.

Finally, a few red flags. Perhaps the central problem of transhuman enhancement of the ear is that it appears to promise unlimited capacity yet remains untempered by reality and experience. It is indicative, then, that Stelarc’s “Extra Ear” rapidly became nonfunctional, and that Chorost, in his auto-ethnographic reflections on cochlear implants, cautions against unchecked optimism:

Replacing the ear with a metal/ceramic/silicon substitute is akin to fixing a spider web with yarn. This is no insult to the engineers. . . . It is rather a recognition of how exquisitely complex and integrated a normally functioning body is, and how little we understand of it. And that’s just the ear. . . . In real life, cyborg body parts need frequent tinkering and constant battery changes, and they are never as good as the natural organs they replace.179

If auditory cilia and the vestibulocochlear nerve are part of an “original prosthesis” that defines the bubble of our musical-auditory environment, the story of prosthetic auditory technology teaches likewise that this cannot be replaced straightforwardly, that it is unrealistic to assume cyborg technologies “will in themselves lead to expanded human capabilities.”180 Related to this, tensions between the grounded reality of amputation and the airborne metaphor of “prosthesis” can give rise to frustrating imprecision, even insensitivity, in enabling a discourse unmoored from firsthand experience. For Vivian Sobchack, herself an amputee, the metaphor has become a vague “catchword . . . for a broad and variegated critical discourse on technoculture that includes little of these prosthetic realities. . . . I’ve no desire for the ‘latest’ in either literal or figural body parts. All I want is a leg to stand on, a limb to go out on—so I can get about my world with a minimum of prosthetic thought.”181 Here one ultimately begins to reckon with the hubris and—for some—potential futility of an anthropocentric drive to enhance the human sensory apparatus.

Further pushback emerges when one asks what index or regulatory force will establish boundaries for the limits of perception if one’s sense
capacities were to be extended. Experiential boundaries—whether gravity, life span, or auditory apparatus—guarantee the concept of reality for each individual, and are therefore essential for the stable conditions needed for meaning creation. With sensory enhancement technology, it is the means by which we shore up identities—our own ego as well as others’—that are at stake. And what is potentially frightening, as Bernard Williams once put it, is not so much the “evil uses of technology as the evil consequences of its good uses, [whose] results . . . we are afraid to dream about.”¹⁸² We glimpse such anxieties in comments by Charles Graser, one of the first patients to receive a portable implant, who reflected on his alien vulnerability: “This electric cochlea testing does bother you. It’s like having someone say, ‘Have a seat in the electric-chair while I fiddle with controls.’ It may not hurt, but it is sometimes frightening in its intensity and your inability to control it.”¹⁸³ By integrating a definition of self with the environment in this way, one view would be to say this condition ultimately leads to an indeterminate self, a distributed ego that is no longer conceptually autonomous; another would be to say it expands the self by redefining the ego-body axis according to the sensory apparatus we control. After all, it is precisely the lack of control (and concomitant rupture of identity) that gave rise to Graser’s anxiety in early implant testing.

In this context, agency is negotiated. The least stable act here is the dissociation of the body from a sense of self. The body remains our bastion of ego and—for many—continues to assert alterity relations with technology. Emmanuel Levinas coined the term alterity to capture the radical difference posed to any human by another, rather than by the machinic. Extrapolating drastically from the tradition’s emphasis on the non-reducibility of the human either to an object (in epistemology) or to a means (in ethics), he positions the otherness of humans as a kind of infinite difference, one that is expressed concretely in face-to-face encounter. Adapting his term to the present discussion tacitly requires us to efface conceptual differences—no less—between biological and non-biological parts as a first principle. In some respects, anthropologists and biologists have been doing this for years,¹⁸⁴ meaning that any conceptual leap is perhaps beside the point, and Levinas’s concept still provides the discursive framework within which “users” may in the future come to terms with the technological other.

Within the slew of quasi-scientific speculations that pepper the transhumanist literature, depictions of evolution through technology often proceed too quickly to be palatable. When Darwin first defined evolution, its key characteristic was incremental change: “If it could be demonstrated that any complex organ existed, which could not possibly have been formed by numerous, successive, slight modifications,” he proclaimed,
“my theory [of evolution] would absolutely break down.”\textsuperscript{185} Put another way, successive slight modification celebrates human frailty, and perhaps the simplest reading of Umwelt theory is precisely that of gradually shifting characteristic limitations that “make us human.” Is it not the straining against the possible in performance that elicits empathy (or envy)? If so, to what extent can this view remain intact in a transhuman context? The dilemma appears intractable if one adheres to an alterity relation between human and other, for a machine’s version of the Chopin-Godowsky Études is considerably less arresting than David Saperton’s, just as a “human” performance of Conlon Nancarrow’s rhythmic Studies for Player Piano excites our empathy in a way quite different to that of its intended mechanical performance. But alterity is not the only way of conceiving oppositional identity, as noted above. And a similar mediating logic underscores Tomlinson’s argument in the context of prehuman sonic cultures that “humanists will have a central role to play” in the debate over biological emergence “insofar as [this] concerns human cultural attainments, even across evolutionary time scales.”\textsuperscript{186}

Such arguments return us to the underlying matter of what status the biological body has in music perception and performance for a century saturated in ongoing technological endeavor. Apple-Cochlear now transmit digitally captured music and voices directly to the nervous system of hearing-impaired listeners, and against the cautionary red flags above, such conspicuous innovations cannot easily be ignored. As we have seen, the discourse of transhumanism sees the body as an assemblage subject to variation. Viewing the body as upgradable technology carries the startling corollary that music need not always be conceived and composed according to our biological limits; and that new perceptual tools may eventually help us to hear, or otherwise experience, existing repertories afresh.\textsuperscript{187} Naked listening may itself become ever more quaint vis-à-vis the creative largesse of mediated listening (casting listeners out of a kind of otological Eden?). Transhumanism in this sense offers a new intellectual framework for measuring the connection and compatibility between listeners and their environment. One need not buy into the relentless linear narrative—that we must become cyborgs or risk extinction—in order to create the intellectual elbow room within which to conceive of musical sound as a mediation of environment, listener physiology, cognition, technology, and sense mechanism. Rather, this assemblage of agencies, its distribution across multiple platforms, and our capacity for physical change mark the beginnings of what we might usefully call a transhuman understanding of the musical ear.
Notes

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4. David Huron found that “for musical textures employing relatively homogenous timbres, the accuracy of identifying the number of concurrent voices drops markedly at the point where a three-voice texture is augmented to four voices.” Huron, “Voice Denumerability in Polyphonic Music of Homogeneous Timbres,” *Music Perception* 6 (1989): 361–82, at 361.


11. Such an argument stretches back at least to David Hume’s empiricism and the theory of primary and secondary sense qualities.

12. Merleau-Ponty stands in a long line of theorists aligning the identity of art with its physically embodied existence. “The meaning of a work of art or of a theory is as inseparable from its embodiment as the meaning of a tangible thing—which is why the meaning can never be fully expressed.” Merleau-Ponty, Sense and Non-Sense, 4.

13. Mangeot seeks to verify the inaudibility of the super B by arguing that “this can be proved by striking a major seventh with the top C of a piano that has the two extra notes; it will sound exactly like an octave.” If this verdict is debatable for a pitch still within the 88-key span of the piano, it is worth recalling that the overtones of any acoustic instrument continue beyond our auditory threshold. See André Mangeot, “Arnold Schoenberg’s Concerto for Violin and Orchestra, Op. 36,” The Strad 50, no. 599 (March 1940): 420–24, and 50, no. 600 (April 1940): 450–56, at 450. Emphasis added.


15. In many cases, such effects may simply be the unintended consequences of notational decisions that need not be taken too seriously. After all, such moments are anomalous in Western art music. Yet anomalies clarify what is consistent in non-anomalous phenomena, presenting the possibility of difference, and of other
categories. Thomas Kuhn famously argued that it was anomalies—becoming the insistent focus of practitioners—that lead to paradigm changes. Kuhn, The Structure of Scientific Revolutions (Chicago: University of Chicago Press, 1970).


20. This precedes even the basic assumption from structural linguists that all communication rests on a principle of common coding. See Roman Jakobson, Language in Literature, ed. Krystyna Pomorska and Stephen Rudy (Cambridge, MA: Harvard University Press, 1987), 451ff.


22. Ibid., 19.


26. Helmholtz, Sensations of Tone, 18, 151.


29. John Augustine Zahm writes that “no one can doubt the skill of Herr Appunn as a mechanician. . . . We are consequently, by the very necessities of the case, compelled to accept Herr Appunn’s estimate as that of an expert and that he is an expert in his specialty no one can gainsay.” Zahm, Sound and Music, 83–84. As late as 1925, Alexander Wood copied Helmholtz in citing Preyer’s work before proclaiming, “It may be safely asserted that our ears are sensitive to sounds having frequencies lying between about 30 vibrations per second and 40,000 vibrations per second.” See Alexander Wood, The Physical Basis of Music (Cambridge: Cambridge University Press, 1922), 22.


39. “Aber wir könnten die Zeitverkürzung des eigenen Lebens in Gedanken noch weiter treiben, bis diese Aether-Schwingungen, die wir jetzt als Licht und Farben empfinden, wirklich hörbar würden. Und könnte es in der Natur nicht noch ganz andere Schwingungen geben, die zu schnell sind, um von uns als Schall empfunden zu werden, und zu langsam, um uns als Licht zu erscheinen? ... Es ist keinesweges widersinning, so etwas zu glauben ... Giebt das nicht vielleicht ein Tönen des Weltraumes ... hörbar für ganz andere Ohren als die unsrige?” Ibid., 31–32.


41. Ibid., 214.

42. Ibid., 215.

43. Ibid., 213–14.

44. Ibid., 207.

45. By this I mean artworks as immanent objects that subsist as part of the universe, which are enfranchised by the work concept. Philosopher C. E. M. Joad, for one, posited Shakespeare’s *Hamlet* as a “subsistence object”—an entity, neither material nor mental, that cannot be identified with its script or any individual production, and that constitutes part of the universe, and possess a special quality of being in its own right. Joad, *Guide to Philosophy* (1936; New York: Dover, 1957), 266–70.


48. Most prominently, Eric Clarke describes the experience of musical meaning as “fundamentally—though not exclusively—a perceptual experience ... [within] a highly structured environment subject to both the forces of nature ... and the profound impact of human beings and their cultures.” Clarke, *Ways of Listening* (New York: Oxford University Press, 2005), 8, 17.

attitude has perhaps been most extensively delineated in the context of analytical training from the theorists historically linked to notions of “structural hearing” (in which an understanding of prolongation and fundamental laws helps the ears form mental models of sonic relationships, leading—for Carl Schachter—to “hearing that is incomparably clearer and more comprehensive that it had been before”) to discourses of the “ideal” listener modeled in different contexts, from Carl Dahlhaus’s “ideal” listener as the assumed perception of a composer’s intentions, and Nicholas Cook’s “ordinary listener,” as one who hears without the apparatus of music-theoretical knowledge, to composer Frank Cox’s “ideal perception,” which measures the information a listener grasps aurally in performance compared to its complex notation. In all cases the perceptual acts a listener accomplishes are determined by their learning experience and cultural situatedness. See Felix Salzer, *Structural Hearing* (New York: C. Boni, 1952), viii; Carl Schachter, *Unfoldings*, ed. Joseph Straus (New York: Oxford University Press, 1999), 35; Nicholas Cook, *Music, Imagination, and Culture* (Oxford: Oxford University Press, 1990), 158; and Frank Cox, “Notes Toward a Performance Practice for Complex Music,” in *Polyphony & Complexity*, ed. Claus-Steffen Mahnkopf, Frank Cox, and Wolfram Schurig (Hofheim: Wolke, 2002), 70–132, at 72.

50. If you believe that language can contain and circumscribe reality, it follows that what cannot be said—or in our case, heard—does not exist. The point is linked *prima facie* to Herder’s critique of language in which thought is bounded in scope by language, and meaning becomes concerned with identifying the usage of words. See particularly “Fragments on Recent German Literature” (1767–68), in *Herder: Philosophical Writings*, ed. and trans. Michael N. Forster (Cambridge: Cambridge University Press, 2012), 33–65. The broader debate between language that “expresses” and that which “regulates” the world in the late eighteenth century has been summarized by Charles Taylor, in “Language and Human Nature,” *Philosophical Papers*, 2 vols. (Cambridge: Cambridge University Press, 1985), 1:215–47, esp. 228.


53. In this context the First World War has been read by Peter Sloterdijk, among others, as a cultural event predisposed toward annihilation of the liberal subject, after which the concept of ego rings hollow even before it was named, as “an inheritance without testament.” Sloterdijk, *Critique of Cynical Reason*, trans. Michael Eldred (London: Verso, 1987), 386.


55. Ibid. This footnote is appended to Freud’s line: “Das Ich ist vor allem ein körperliches, es ist nicht nur ein Oberflächenwesen, sondern selbst die Projektion einer Oberfläche.” (The ego is first and foremost a bodily ego; it is not merely a surface
entity, but is itself the project of a surface). The Standard Edition explains that it first appeared in the 1927 English translation where it is described as “having been authorized by Freud.” It does not appear in the German edition.

56. In its narrowest meaning, Helmholtz’s concept of a “mental ear” (geistige Ohr) connotes how directed attention alters the perception of what is empirically given via the senses. Benjamin Streege contextualizes Helmholtz’s terms in Helmholtz and the Modern Listener, 73–79; and Veit Erlmann offers a nuanced account of how he came to terms with “the growing sense of distance between interior and exterior” where anatomical science is “blind” without “some sort of philosophical guidance” in Reason and Resonance (New York: Zone, 2010), 217–70, at 220.


58. “The task of biology consists in expanding in two directions the results of Kant’s investigations: (1) by considering the part played by our body, and especially by our sense-organ and central nervous system, and (2) by studying the relations of other subjects (animals) to objects.” See Uexküll, Theoretical Biology [1920] (New York: Harcourt, Brace & Company, 1926), xv.


60. Uexküll, Umwelt und Innenwelt der Tiere (Berlin: Springer, 1909).


62. Ibid., 135. This was not in fact a new observation; Uexküll merely inserted it into an argument about biological determinism. Back in 1852, the writer and Wagner-advocate Richard Pohl made much the same point when questioning utopian claims for an equal artistic-scientific culture: “the physicist concerned with sensory impression fails to ask where he is going ... the composer with facts of harmony fails to ask where he is coming from.” Pohl, “Akustische Briefe: Erster Brief,” Neue Zeitschrift für Musik 2 (1852): 13. The history of species-specific perception was itself anticipated in early nineteenth-century phrenology. Johann Spurzheim declared that “the world is different to every species of animal, and even to every individual of the same species. ... It is evident that every sentient being perceives impressions in proportion to the number and energy of its sentient faculties.” See Spurzheim, The Physiognomical System (London: Baldwin, Cradock & Joy, 1815), 528–29.

64. Two examples concern differing degrees of myopia among people, and different common environments: “The stars are still more different [than the sun, for different viewers]. A person with medically flawless eyesight looking at the night sky sees small, shiny discs while another sees themselves illuminated by small bright lamps surrounded by a corona. . . . All those who spend long periods of time in the countryside discern many more things [among nature] than city dwellers.” Uexküll, “Wie sehen wir die Natur und wie sieht sie sich selber?,” 265–66.

65. “Da die Merkfähigkeit der Menschen ausserordentlich wechselt, müssen auch ihre Merkwelten voneinander abweichen. Mit seiner Umwelt steht der einzelne Mensch nicht nur mittels seiner Sinneswerkzeuge, die eben das Merken ermöglichen, in Verbindung, sondern auch dank seiner Handlungswerkzeuge, die ihn mit seiner Wirkungswelt verbinden. Merkwelt und Wirkungswelt bilden gemeinsam die Umwelt. . . . Dadurch warden die Umwelten so entscheidend umgestaltet, daß man von Berufswelten reden kann.” Ibid., 266.

66. For Uexküll the critical difference to Helmholtz’s sensory qualities—“signs of an external phenomenon . . . [which] remains forever unknown to us”—was that of materialism to transcendentalism: received sensation for him constitutes itself the real of an external object rather than its sign; “Helmholtz indeed acknowledged that all objects must appear different to each subject,” he qualifies, “but he was seeking the reality behind appearances.” By analogy, Helmholtz’s position would imply the work concept as the neo-Platonic “reality behind [the] appearance” of performance. See Uexküll, Theoretical Biology, xiv, xv; and Stefan Helmreich “Remixing the Voyager Interstellar Record: Or, As Extraterrestrials Might Listen,” Journal of Sonic Studies 8 (2014).

67. Although for Uexküll the cinematograph offers proof that the smallest conceptual moment of human perception lasts an eighteenth of a second, a tick is capable of waiting eighteen years without eating before the signal of butyric acid from a passing mammal stimulates it to activity. “Time stands still in the tick’s waiting period,” concludes Uexküll, who assumes an unchanging environment could only be endured by perceptual hibernation, “not just for hours but for years.” Uexküll, A Foray into the Worlds of Animals and Humans, 52.


69. That is, perceiving the world of a bee or a bat, for instance, by seeing the polarization of light or by seeing into the ultraviolet range of the spectrum. Though he clarifies that “the observer can advance in no way other than on the basis of the picture offered to him on the inside of his own bubble.” (Der Beobachter kann gar nicht anders vorgehen, als durch Zugrundelegung des Bildes, das sich ihm auf der Innenseite seiner eigenen Seifenblase bietet.) Uexküll, “Wie sehen wir die Natur und wie sieht sie sich selber?,” 266.


72. Uexküll, Theoretical Biology, 76.


75. Joseph Straus, “Normalizing the Abnormal,” JAMS 59 (2006): 113–84. Straus, in his pioneering work of disability studies and music, emphasizes the historicity of the concept of physical normality, and its emergence in the early nineteenth century from which disability became understood as a deviation: “neither natural nor permanent, and thus subject to possible remediation” (114). This is set against the broader view within disability studies that any concept of normal is relative to a given culture, within which it represents a statistically predominant physical condition. Impairment, by contrast, represents an empirical deviation therefrom. The most cogent historical account to date is Michel Foucault, Abnormal (Picador, 2007), 26ff. For a comprehensive overview of this burgeoning field, see The Oxford Handbook of Music and Disability Studies, ed. Blake Howe, Stephanie Jensen-Moulton, Neil Lerner, and Joseph Straus (New York: Oxford University Press, 2015).


80. Uexküll, Theoretical Biology, 205.


83. This principle of experimental psychology—when people “consider a particular value for an unknown quantity before estimating that quantity”—applies typically to numerical values in experiments, but there is no reason to restrict the principle it


85. Stumpf, Tonpsychologie, 1:viii. See also Don Ihde’s argument for a philosophy of listening as the “hope to find material for a recovery of the richness of primary experience,” in Listening and Voice: Phenomenologies of Sound, 2nd ed. (Albany: State University of New York, 2007), 13.


88. He defined transhumanism as “philosophies of life . . . that seek the continuation and acceleration of the evolution of intelligent life beyond its currently human form and human limitations by means of science and technology, guided by life-promoting principles and values.” Max More, “The Philosophy of Transhumanism,” in The Transhumanist Reader, 3.


95. The eight characters have absurdly humanistic names: text, pretext, context, heterotext, mythotext, paratext, metatext, and posttext. Ihab Hassan, “Prometheus as Performer,” Georgia Review 21 (1977): 830–50, at 843. Hassan acknowledged the term posthumanism as a “dubious neologism,” but anticipated the transhumanizing process not as a sudden change but as a natural part of being human, a condition that combines “Imagination and Science, Myth and Technology.” It began with the discovery of fire by prehistoric “man,” he asserts; that is, with the mind of Prometheus (835).
96. Among the scholarly literature, two representative contributions would be Donna Haraway’s seminal essay “A Cyborg Manifesto” (1983); and Jane Bennett, *Vibrant Matter* (Durham, NC: Duke University Press, 2010).


106. “eine Organprojektion oder die mechanische Nachformung einer organischen Form.” Kapp, *Grundlinien*, 71. The book drew broadly on an Aristotelian techne—the ability to make (something) that depends on correct awareness of, or reasoning about, the thing to be made—and more specifically on Democritus’s view of technology as the imitation of nature, in which human house-building and the craft of weaving were first invented by imitating swallows building their nests, and spiders weaving their webs, respectively.

107. Kapp, *Grundlinien*, 93. The most widely accepted instance of organ projection, one that Kapp cites simply as “obvious,” is that between the nervous system and networks of telegraphic communication that were established throughout Europe and North America during the middle decades of the nineteenth century. This
parallel—asserted by such respected academic physiologists as Du Bois Reymond, Helmholtz, and Werner Siemens—serves to authenticate Kapp’s substantialist conception of organ projection: “Nerves are cable installations of the animal body, telegraph cables are human nerves. And, we might add, so must they be, for the characteristic feature of organ projection is the unconscious occurrence.” (Die Nerven sind Kabeleinrichtungen des tierischen Körpers, die Telegraphkabel sind Nerven der Menschheit! Und fügen wir hinzu, sie müssen es sein, weil das charakteristische Merkmal der Organ projection das unbewußte Vorsichgehen ist) (141). For a detailed discursive study of the parallelism between nerves and networked telegraphic cables in nineteenth-century Germany, see Laura Otis, Networking (Ann Arbor: University of Michigan Press, 2001).


109. The classic text is McLuhan, Understanding Media: The Extensions of Man (1964), where he argues that with electronic communication technology “we are extending our central nervous system itself in a global embrace.” Media, he continues, are effectively metaphors that “translate experience into new forms” and he prophesies a dominant culture of electronic data transfer accordingly: “By putting our physical bodies inside our extended nervous systems, by means of electric media, we set up a dynamic by which all previous technologies that are mere extensions of hands and feet and teeth and bodily heat-controls . . . will be translated into information systems” (3 and 57).

110. Kittler, Gramophone, Film, Typewriter, 189.

111. Ibid., 16. Emphasis added

112. Brian Massumi, for one, proposes that “things and objects are literally, materially prosthetic organs of the body” in Parables for the Virtual, 96.

113. Hayles, How We Became Posthuman, 283.

114. Six years before Claude Palisca published his famously positivistic definition of “American Scholarship in Western Music” (1963), the American intellectual Dwight Macdonald launched a related critique: “We want to know how, what, who, when, where, everything but why.” Rolling his eyes at the practice of weighing criminals before and after execution, he saw in its quest for different weights an emphasis on data and a lack of theory: “We are obsessed with technique, hagridden by Facts, in love with information . . . our scholars—or more accurately, our research administrators—erect pyramids of data to cover the corpse of a stillborn idea.” See Macdonald, Masscult and Midcult (New York: New York Review of Books, 2011), 208, 203. More recent resistance to a posthuman philosophy include complaints from computer scientist David Gelernter, for whom a “roboticist” worldview has well-nigh become “a social disease” that adheres to a “fatally flawed” analogy between mind and software. See Gelernter, “The Closing of the Scientific Mind,” Commentary Magazine, 1 January 2014, https://www.commentarymagazine.com/article/the-closing-of-the-scientific-mind/.


117. Ibid., 284. Emphasis added.


119. This extends from Alvin Lucier’s Music for Solo Performer (1965) and Raymond Kurzweil’s Brain-Generated Music to the Brain-Computer Music Interface developed at Plymouth University, UK. Whereas Lucier’s approach was to amplify alpha waves, creating a signal to excite loudspeakers attached to percussion instruments, Brain Generated Music Interface analyses the electrical activity in the Brain (via electroencephalography) and converts the signal into music played on a MIDI keyboard. An overview is given in Eduardo R. Miranda and J. Castet, Guide to Brain-Computer Music Interfacing. Kurzweil describes BGM as a “brain-wave biofeedback system” whose stated purpose is to encourage “the generation of alpha waves [associated with meditative states] by producing pleasurable harmonic combinations upon detection of alpha waves, and less pleasant sounds and sound combinations when alpha detection is low.” See his description in The Age of Spiritual Machines, 152. An analysis of Lucier is given in Volker Straebel and Wilm Thoben, “Alvin Lucier’s Music for Solo Performer,” Organised Sound 19 (2014): 17–29.

121. Sciarrino, notes from Hermes in L’Ope re per Flauto (Milan: Ricordi, 1984), 7.


123. Helmholtz, On the Sensations of Tone, 94.


125. Officially, thresholds of audibility are calculated in laboratory conditions as the smallest level of sound pressure needed for an individual to perceive a certain frequency. They are plotted as the thresholds in decibels (sound pressure level: SPL) versus frequency (Hz). Of course, the auditory system remains insensitive to some frequencies no matter how intense the sound. Values are calculated through psychometric testing where subjects are deemed to have heard a tone if they correctly detect it 75 percent of the time. The American National Standards Institute (ANSI) publishes data for the audibility thresholds of “ontologically normal persons” 18–25 years old. See document ISO 28961:2012 here https://webstore.ansi.org/RecordDetail.aspx?sku=ISO+28961%3a2012 http://webstore.ansi.org/RecordDetail.aspx?sku=BS+ISO+28961%3A2012.

126. A crescendo leads to a peak dynamic ranging from PPP to FF, before a diminuendo. Typically for Sciarrino, the passage into silence is specified by a circle at the head or tail of each pair of lines, as the preface explains: “Crescendo dal nulla / diminuendo fino al nulla.” Sciarrino, Sei capprici, 1.

127. Aristotle, de Anima, Book 2, 424a, ll. 28–32.


133. Voegelin, Sonic Possible Worlds, 170. Imagining inaudible sounds becomes a metaphor in Voegelin’s reading for political open-mindedness. She moralizes that the
possibility is always there, and that “we need ... the [idea of the] inaudible, to become able to imagine the as yet unimaginable and let it infiltrate actuality.”

134. Ernst, Sonic Time Machine, 30.

135. The ultrasonic pitches, though calculable, are not determined as such. Directions in the score explain: “2 ‘dog whistles,’ poss. high pitched (together producing deep difference tone by ff).” Nørgård further requests that players take “great care . . . to maximize the ‘overall production’ of difference-(beat)-tones” by adopting stable tone quality, before the two whistles outlast the chord proper and a general pause on the rest clears the altitudinous sound. The second and final appearance of the whistles hears their difference tones emerge as the sole sound from within a sustained chord of dissonant semitones, struck fff and slowly detuned via quarter tones in a descending glissando. Nørgård, Fifth Symphony (Copenhagen: Wilhelm Hansen, 1991), 53, 57.


140. The distinction between medical treatment that enhances function rather than ameliorates an illness, has been regarded as fuzzy by philosophers in this context. Witness Carl Elliott, who argues that what seem to us like straightforward examples of medical treatments “will look differently to people from other times and other places, and ... the line we often draw between enhancements and treatments is not as sharp as we would like to think.” Elliott, “What’s Wrong with Enhancement Technology?,” in Readings in the Philosophy of Technology, ed. Kaplan (Plymouth, UK: Routledge, 2009), 431–37, at 435.

142. One example is the Interactive Music Awareness Programme (IMAP) based at Southampton University, UK. See http://morefrommusic.org.

143. Douglas McCreery of Huntingdon Medical Research Institute has pioneered this method for patients with type 2 Neurofibromatosis (NF2), where a tumour along the auditory nerve leaves it without function after surgery to remove the tumour. See McCreery, “Cochlear Nucleus Auditory Prosthesis,” Hearing Research 1 (2008): 64–73.


145. By contrast, commercial headphone manufacturers have developed bone-conduction technology for normative hearing ranges as a means of bypassing the eardrum, but this ceases to function beyond normative thresholds. One example is AudioBone: http://www.audioboneheadphones.com.


147. For theorists of virtuality such as Massumi, the discovery of aesthetic stimuli in newly accessible objects would not constitute an “authentic” reach into the world of supersensible sounds. Adapting his critique of sensation, any technological extension of the cochlea duct’s acuity points to the virtual: “Sensation and thought, at their respective limits as well as in their feedback into each other, are in excess over experience: over the actual. They extend into the nonactual [what cannot be perceived]. If the alternative mode of abstraction into which perception extends is the possible, the intense mode of abstraction into which sensation potentially infolds is, at the limit, the virtual.” Massumi, Parables for the Virtual, 98.


150. Graeme Clark, “The Development of Speech Processing Strategies for the University of Melbourne/Cochlear Multiple Channel Implantable Hearing


155. Eisuke Yanagisawa’s album *Ultrasonic Scapes* (2011) sold out of its initial release of fifty copies, but is available as a digital download: http://www.gruenrekorder.de/?page_id=5260.


158. In 1999 Rainer Klinke et al. demonstrated a seven-fold increase in the brain size of congenitally deaf cats whose auditory nerves received electrical stimuli (via neural implants) from a microphone; the implant was connected to a microphone, effectively creating a prosthetic ear that allowed the hitherto deaf cats’ functioning auditory nerve to “hear.” See R. Klinke, A. Kral, S. Heid, J. Tillein, and R. Hartmann, “Recruitment of the Auditory Cortex in Congenitally Deaf Cats by Long-Term Cochlear Electrostimulation,” *Science* 285 (1999): 1729–33.


160. Stockhausen’s comment is cited in Robin Maconie, *Other Planets* (Lanham, MD: Scarecrow Press, 2005), 145; Carr was a graduate student in Physics at Cornell at the time of the nanoguitar’s invention. See: http://www.news.cornell.edu/stories/1997/07/worlds-smallest-silicon-mechanical-devices-are-made-cornell.

One example, developed at the Swiss Federal Institute for Technology, is the “bionic hand” whose neurally embedded electrodes offer a vicarious sensation of touch. Dennis Aabo Sørensen’s “hand” conducts electrical signals from his prosthetic fingers to his brain, giving him a replacement sensation of touch in his amputated hand. Electronic sensors detect tension in the artificial tendons that control his finger movement; this information is converted into an electric current; a computer in the hand sends an impulse to ultra-thin electrodes that have been surgically implanted into the nerves in the upper arm, which then relay to signal the brain. See Stanisa Raspopovic et al., “Restoring Natural Sensory Feedback in Real-Time Bidirectional Hand Prosthesis,” 1–10, http://biofag.com/files/Sci_Transl_Med-2014-Raspopovic-222ra19.pdf.


The “Extra Ear” itself is part subcutaneous Medpor scaffold, part organic matter grown from stem cells and mature adipocytes; it was developed in consultation with surgeons Malcom A. Lesavoy, Sean Bidic, and J. William Futrell in Melbourne. Stelarc had discussed the project with medical consultants as early as 1997, he explains, and it went through a decade of frustrated attempts—including consideration of various possible locations—before proceeding to a permanent modification of his body architecture. See http://stelarc.org/?catID=20242.


An introduction to Nucleus 7 is given here https://cochlearimplanthelp.com/tag/nucleus-7/.


Stelarc’s own account of the “extra “ear” project is here http://stelarc.org/?catID=20242.

To an extent, ventriloquizing an illusory voice inside one’s head externalizes the function of Theodor Reik’s figurative “third ear,” that of unconscious psychoanalytical intuition, in *Listening with the Third Ear* (New York: Farrar, 1948).

Comment taken from a private email received on 18 November 2017.


177. Helmholtz, *Sensations of Tone*, 18, 151.

178. Rudolph König’s term for imagined ultrasonics at the time.

179. That Chorost’s device only just achieved parity with his earlier auditory environment (hearing aids) doubtless colors this cautious conclusion. Chorost, *Rebuilt*, 175, 177.

180. Ibid., 174.


187. Don Ihde, speaking of a “postphenomenology” in which digital mediation renders accessible male mice singing courting songs and the changeable cycles of whale song, reflects in similar vein that “the possibilities of musics not yet heard . . . are far from exhausted.” Ihde, *Listening and Voice*, 264.